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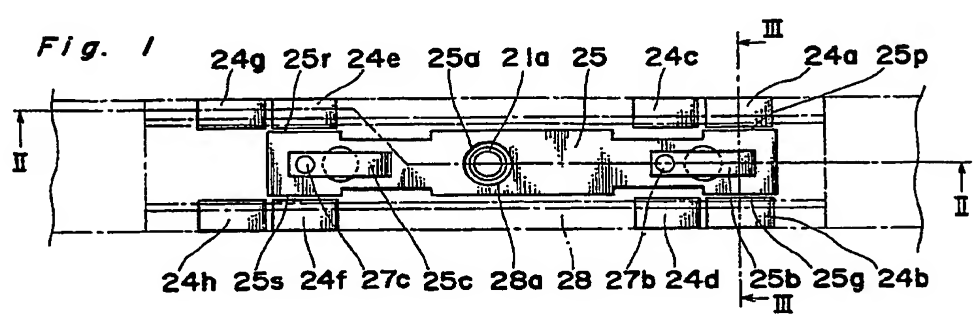
(54) **Ink recording apparatus.**

(57) An ink recording apparatus used with printers or the like and manufactured by applying semiconductor device manufacturing techniques. One wall of an ink chamber (20) is formed of a single-crystal substrate (21) and an ink jet port (21a) is formed by etching on the single-crystal substrate (21). The ink chamber (20) has a pressure-applying unit (60) therein, and the pressure is applied to ink within the ink chamber (20) so that the ink is jetted through the ink jet port (21a). The pressure-applying unit (60) has piezoelectric elements (60a). A shutter (25) and electrodes (24a to 24h) composed of polycrystalline-silicon film are formed on the single-crystal substrate by film forming in the LPCVD method and patterning through plasma etching. A front wall (28) is formed by coating the shutter (25) and electrodes (24a to 24h) further with a polycrystalline-silicon film. The shutter (25) is movable between the wall surface of the ink chamber (20) and the front wall (28), being driven through electrostatic attracting force produced between voltage-applied electrodes (24a to 24h) and the shutter (25). The electrodes (24a to 24h) are formed at positions corresponding to those where the shutter (25) blocks the ink jet port (21a) and releases the same.

Fig. 1



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BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to an ink recording apparatus for use in printers or the like. It is to be noted that the word recording, herein used refers to the fact that any desired patterns of characters, symbols, or the like are written down onto a printed material such as paper with ink jetted out by an apparatus of the present invention.

2. Description of the related art

In conventional ink recording apparatus that are currently used in printers featuring their compactness suitable for office or personal use thereof, two types of ink jet system described below are mainly employed. One of the types is a piezoelectric type in which the ink is applied by piezoelectric elements within a ink chamber. Another type is a thermal type in which the ink generates bubbles by utilization of exoergic of heating elements within a ink chamber.

The piezoelectric type controls diameter of ink droplets well, however, to arrange the piezoelectric elements in high density is so difficult that the ink jet head is forced to become large size. Accordingly, it is impossible for an ink jet head to discharge many ink droplets simultaneously. Then, the ink jet head is required to move for recording many dots. The result is that the ink jet head takes a long time to record a predetermined size image from the overall point of view of the recording speed, even if the frequency of ink droplet discharge can be increased within a feasible range. And also, the moving mechanism for the ink jet head is required, which prevents the ink recording apparatus from increasing its compact and lightweight performance, its quite performance and decreasing demanded power and cost.

On the other hand, the recording speed of thermal type can be increased enough, because a line head can be manufactured easily by substantially integrating the heating elements. However, it needs an independent ink chamber and a nozzle for each heating element. The thermal type ink recording apparatus having such structure requires a high work precision in manufacturing thereof. The work precision and positional precision between a substrate provided with the thermal elements and the ink chambers have effect on ink jet amount so that not only the control of ink droplet diameter and also the manufacturing of head becomes difficult accompanying a cost up. Moreover, since the integrating yield of heating elements does not reach the practical level, its cost becomes enormous actually.

A conventional ink recording apparatus is shown in the Japanese magazine "Nikkei Mechanical", issued on May 29, 1989, pp. 90 to 91, the apparatus exemplifying such ink recording apparatus that solves such problems as described above.

Fig. 14 shows a construction of such a conventional ink recording apparatus. In the figure, a slit plate 1 is provided with a plurality of slits 2 having a width of 50 µm and a length of 8 mm in place of nozzles. The slit plate 1 has also a plurality of auxiliary holes 3 equal in number to a plurality of heating elements 5 formed on a base plate 4, with an ink reservoir 6 as well provided to the slit plate. On the base plate 4 there are formed a plurality of electrodes 7 in correspondence to the heating elements 5 and moreover a plurality of fluid resistance elements 8 shaped into a long, narrow protrusion. Besides, between the slit plate 1 and the base plate 4 there is disposed a spacer 9, which in conjunction with the slit plate 1 and base plate 4 defines a portion serving as an ink chamber 11 illustrated in Figs. 15a to 15d. Under the base plate 4 there is provided an ink tank 10, whereon all the units are piled up to make up a head. The heating elements 5 is formed by piling up a glass layer, resistors, electrodes, and a protective coat on the base plate 4, as in a common thermal head.

A conventional ink recording apparatus having a construction as described above will jet ink droplets while taking steps as shown in Figs. 15a to 15d. Each step is detailed below:

(a) First, when pulse voltage is applied to the heating elements 5 on the base plate 4 to heat the ink contained in the ink chamber 11, the ink in the vicinity of the heating elements 5 vaporizes to make a large number of small bubbles 12;

(b) Second, the small bubbles 12 merge together and grow into a larger bubble 13 that overcome the surface tension, causing ink swells to be produced at the slits 2;

(c) Third, when the heating elements 5, on completion of heating, are cooled down to stop the bubble 13 from being produced, the swelling of ink is intercepted to produce ink droplets 14; and

(d) Finally, the ink droplets 14 are jetted out through the slits 2 by the power of growing bubble 13.

If a number of heating elements 5 share the slits 2 and the ink chamber 11 with one another as in the above conventional apparatus, there arises a

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problem that the ink droplets 14 derived from adjoining heating elements 5 may interfere with each other. In the conventional apparatus, however, the fluid resistance elements 8 provided between adjoining heating elements 5, 5, as shown in Fig. 14, will serve to prevent pressure waves from being horizontally propagated while the bubbles are being produced, thereby allowing the ink droplets 14 to be formed and jetted out without being adversely affected by such pressure waves. Furthermore, the auxiliary holes 3 provided to the slit plate 1 will absorb the pressure waves, so that pressure waves may be prevented also from being reflected.

In the conventional apparatus having arranged as described above, however, the heating elements 5 must eventually be used in the apparatus, that does not lead the cost of ink jet head to a substantial reduction, and since the heating elements 5 need cooling, the recording speed is not increased substantially. Further, during the alternating between a heating and cooling under the condition in which the heating elements 5 are wetted with ink, the burnt ink is caused to adhere to the surface of heating elements 5, then the growth of the burnt ink changes gradually the initial ink jet performance, and an inferior recording occurs finally. When the adhesion of burnt ink in which a coloring matter like an organic dye and thermally decomposed carbon of different types of additives are mainly included progresses on the surfaces of the heating elements 5, not only the bubbles 12 are generated inhomogeneously but also the heating elements 5 are thermomechanically fatigued and finally destroyed. Moreover, when the burnt ink is suspended in the ink, it will stop up the slits 2, preventing the ink droplets 14 from being jetted out therethrough.

With respect to the ink property, in order for the ink to generate the pressure and transmit the pressure to the slits 2, the ink is preferably of a type easy to evaporate and also low in viscosity enough to transmit the pressure faithfully at minimized loss. On the other hand, in order for the ink droplets 14 jetted through the slits 2 to fix on the recording paper (not shown), the ink is preferably of a type hard to dry to avoid any possible clogging in the slits 2 and high in viscosity enough to stabilize the jet of ink travelling toward the recording paper and also to avoid any possible running of ink. Particularly, a cheap recording paper has generally rough surface, since the running of ink is remarkable on such a surface, the ink is required high viscosity and fixing activity enough to select recording paper freely. Thus, th ink is r quired two prop rties which conflict with each other. It is impossible to design such ink that satisfies the two conflicting r quirements. Accordingly, the ink recording apparatus of prior art is forced to sacrific at least one of the three performance elements, that is the lifetime of the heating elements 5, the generating sensitivity of the bubbles 12 and the recording quality. Further, the apparatus needs its own recording paper in which the ink hard to run. These factors increase not only initial cost but also running cost of the apparatus.

SUMMARY OF THE INVENTION

The present invention has been accomplished to effectively solve the above-mentioned technical problems and, accordingly, an essential object of the present invention is to provide an ink recording apparatus which is low in cost, compact in size, light in weight, quiet in operation thereof, superior in durability, superior in recording quality without running of ink, free to select type of recording paper, able to design the best type of ink for the apparatus, and of high reliability.

In accomplishing these and other objects, according to one preferred embodiment of the present invention, there are provided an ink chamber for reserving ink, an ink jet port provided to said ink chamber, pressure-applying means for applying pressure to the ink in said ink chamber, a shutter provided in the vicinity of said ink jet port, said shutter being movable between a shut-off position for preventing ink from being jetted out after passing through said ink jet port and a passing position for allowing ink to be jetted through, and shutter driving means for driving said shutter in response to recording signals.

With the above-mentioned arrangement of the ink recording apparatus according to the first embodiment of the invention, the shutter disposed in the vicinity of the ink jet port make it possible to record dots under the mechanical control of the shutters movement between the shut-off position and passing position thereof. Thus the ink recording apparatus according to the invention is lighter in weight, more compact in scale and lower in cost than the conventional ink recording apparatus of piezoelectric type or thermal type, moreover able to perform a high-density recording with high reliability and superiority in recording quality. Further, the ink recording apparatus according to the invention makes it possible for the ink to be designed most suitably for the apparatus.

According to another preferred embodiment of the present invention, there are provided an ink chamber for reserving ink, an ink jet port provided to said ink chamber, pressure-applying means for applying pressure to the ink in said ink chamber, a shutter provid d in th vicinity of said ink jet port and outside of said ink chamber, said shutter being movable betwe n a shut-off position for preventing ink from being jett d out after passing through said

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ink j t port and a passing position for allowing ink to pass through, shutter driving means for driving said shutter with responding to recording signals, and a wall provided outside of said shutter for covering an external surface of said shutter.

With the above-mentioned arrangement of the second embodiment of the ink recording apparatus according to the invention, the following operational effects can be obtained in addition to those of the ink recording apparatus of the first embodiment. That is, even if the shutter is subject to ink pressure in its shut-off position, the wall disposed on the rear side thereof supports the shutter to prevent the shutter from being deformed. The wall also prevents the internal structure of the apparatus including the shutter from being touched by hands, fingers, or other foreign matters from external, thus ~~enhancing the reliability of the apparatus higher~~ than of the first embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features for the present invention will become apparent from the following description taken in conjunction with the preferred embodiment thereof with reference to the accompanying drawings, in which:

Fig. 1 is a plan view showing the main construction of an ink recording apparatus of a first embodiment according to the present invention;

Fig. 2 is a sectional view taken along line II -II of Fig. 1;

Fig. 3 is a sectional view taken along line III -III of Fig. 1;

Fig. 4 is a schematic diagram showing a peripheral structure of the ink recording apparatus of Fig.1;

Fig. 5 is a block diagram showing a driving circuit of the ink recording apparatus of Fig.1;

Fig. 6 is a view illustrating the operation of the ink recording apparatus of Fig. 1;

Fig. 7 is a sectional view taken along line VII- VII of Fig. 6;

Figs. 8a to 8n are views illustrating the manufacture processes of the ink recording apparatus of Fig. 1;

Fig. 9 is a plan view showing a pattern in which the ink recoding apparatuses of Fig. 1 are integrated;

Fig. 10 is a plan view showing the main construction of a second embodiment of the present invention;

Fig. 11 is a sectional view taken along line XI -XI of Fig. 10;

Figs. 12 and 13 are views illustrating the operation of the ink recording apparatus of Fig. 10;

Fig.14 is a perspective view showing the construction of an ink recording apparatus according to the prior art; and

Figs. 15a to 15d are views illustrating the operation of the apparatus of Fig. 14.

DETAILED DESCRIPTION OF THE INVENTION

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals through the accompanying drawings.

Referring first to Figs. 1 to 3, a single-crystal silicon substrate 21 has an ink jet port 21a provided in the center thereof and an ink sump 21b provided on its side adjoining an ink chamber 20. The ink jet port 21a is formed as bored from the ink sump 21b through an oxide film 22 and a nitride film 23. Electrodes 24a to 24h formed of ~~polycrystalline-silicon, the wiring of which is~~ omitted in the figures, each have on their surfaces a nitride film formed as an insulating layer (not shown) A shutter 25 formed of polycrystalline-silicon has an ink passing hole 25a provided in its center and guide flots 25b, 25c provided on opposite sides thereof. On the surfaces of the shutter 25 except the underside thereof there is formed nitride films (not shown) as lubricating layers. Guide pins 27b, 27c are formed also of polycrystalline-silicon. A front wall 28 illustrated by single dotted chain lines in Fig. 1, is integrated with the guide pins 27b, 27c, has an opening 28a provided in its center and ink recovering grooves 28b, 28c in its both ends. On the other hand, the ink chamber 20 and the ink sump 21b are charged with ink 31 composed of insulating material. The ink 31 is subject to working pressures corresponding to recording signals through ordinary means such as a pressure device comprising a piezoelectric element or a heating element as shown in Fig. 10, which means is not shown.

The component parts shown in Figs. 1 to 3, as detailed later, are integrally manufactured onto the substrate 21 using semiconductor device manufacturing processes including lithography and etching. The result is that the component parts are substantially compact in size, light in weight, and of high precision, comparable to semiconductor products. Therefore, an ink jet head in which the ink recording apparatuses of the present embodiment are integrated is manufactured without difficulty, and it is possible to select the arrangement pattern of the apparatus and/or the arrangement density of them in their integration.

The protection plates 29, 30 shown in Fig. 2 may be manufactured by different method.

The ink 31 is applied pressure by the pressure-applying unit 60 comprised with the piezoelectric device 60a which is driven by the piezoelectric device driving circuit 61 as shown in Fig. 4. The

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driving circuit 61 can drive the piezoelectric device 60a continuously, or intermittently, or at any timing desired so that the ink is simultaneously applied pressure. On the extension of the ink recovering groove 28b extending in the front wall 28, the pump 62 is arranged for recovering ink. The ink is recovered through the groove 28b into the ink chamber 20 by the pump 62. With respect to the groove 28c, the ink is recovered in the same manner that, however, is not shown.

Fig. 5 is a block diagram showing a driving circuit for driving the shutter 25 of the ink recording apparatus here mentioned. In the figure, a control circuit 141 receives a recording signal from the apparatus main body (not shown) via an input terminal 142, subsequently deciding the status of the signal to control switches 143 to 145. The switch 143 serves to turn on and off a power supply 146, while the switches 144 and 145 serve to control one group of connected electrodes 24a, 24b, 24e, and 24f and the other group of like electrodes 24c, 24d, 24g, and 24h, respectively, so as to render the two groups of electrodes oppositely phased. More specifically, while a voltage is applied to the side of the electrodes 24a, 24b, 24e, and 24f, the electrodes 24c, 24d, 24g, and 24h are grounded; and vice versa.

Now the ink recording apparatus arranged as stated above will be explained with respect to its operation. The state thereof shown in Figs. I to 3 is such that the control circuit 141 judges the apparatus to be in ink-jetting operation according to an input signal delivered from the apparatus main body via the input terminal 142, turning on the switch 143 and activating the switches 144, 145, with the result that a voltage of several times 10 V or so is applied to the side of the electrodes 24a, 24b, 24e, and 24f. In this state, the shutter 25 is stably positioned as shown in the figures with its ends 25p, 25q, 25r, and 25s sucked up by virtue of electrostatic attracting force acting between the ends and the surfaces of the electrodes 24a, 24b, 24e, and 24f, where the ink passing hole 25a of the shutter 25 is aligned with the ink jet port 21a. Then, due to the pressure created within the ink chamber 20 by the pressure-applying unit 60, the ink 31 charged in the ink sump 21b passes through the ink jet port 21a and ink passing hole 25a of the shutter 25 and further through the opening 28a of the front wall 28, thus making ink droplets 32 to be jetted out.

At this point of the state of the apparatus, setting recording paper at the outside of the protection plates 29, 30 allows the ink droplets 32 to record any patterns of characters, symbols, and the like. Moreov r, the protection plates 29, 30 surrounding the shutter 25 for coverage serves to prevent operator s hands or fingers and the lik from touching the shutter from external, and foreign matters from entering to the internal structure including the shutter 25.

Succeedingly to the above-mentioned state, even if the control circuit 141 turns off the switch 143 to de-energize the electrodes 24a, 24b, 24e, and 24f, the shutter 25 will remain as stable in rest in the same position thereof primarily by virtue of surface force.

Next, with reference to Figs. 6 and 7, the ink recording apparatus will be described in its states in which the shutter 25 has moved away from the position shown in Fig. 1. In this case, the control circuit 141 judges that the apparatus completed the ink-jetting operation according to an input signal delivered from the apparatus main body via the input terminal 142, changing the condition of the switches 144, 145, with a result such that a voltage is applied to the side of the electrodes 24c, 24d, 24g, and 24h. In this case, as shown in Fig. 6, the shutter 25 is stably positioned in rest as having moved from the position shown in Fig. 1 with its ends 25p, 25g, 25r, and 25s sucked up by virtue of electrostatic attracting force acting between the ends and the surfaces of the electrodes 24c, 24d, 24g, and 24h, where the ink jet port 21a of the substrate 21 is shut off by the shutter 25, so that the ink can not be jetted out through the ink passing hole 25a and opening 28a even if the ink is applied pressure by the pressure-applying unit 60 and jetted out through the ink jet port 21a. At this point of state of the apparatus, even if a sheet of recording paper is set at the outside of the protection plates 29, 30, the shutter 25 does not allow the ink droplets 32 to record any patterns of characters, symbols, and the like.

Succeedingly to the above-mentioned state, even if the control circuit 141 turns off the switch 143 to de-energize the electrodes 24c, 24d, 24g, and 24h, the shutter 25 will remain as stable in rest in the same position thereof primarily by virtue of surface force. The apparatus therefore, even if left unused for a long period, can prevent any recording failure or any head damage. Moreover, the protection plates 29, 30 surrounding the shutter 25 for coverage serves to prevent operator,s hands or fingers or other foreign matters from touching the shutter from external, so that the shutter 25 is not moved thereby.

Much of the ink shut off is backed into the ink sump 21b. The rest part of the ink is recovered into the ink chamber 20 through the rear side of the shutter 25, the grooves 28b, 28c and pump 62, and accumulat d into the ink sump 21b.

Wh n the shutter 25 shuts the ink jet port 21a, the shutt r is applied a pr ssure to jet the ink through the port 21a, supported by the front wall 28 in the manner that the shutter is pushed against the

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front wall 28. Therefore, the shutter 25 is not distorted and keeps always itself stable in its performance. That is, after shifting the shutter 25 from the state described above to the state shown in Figs. 1 to 3, to reset the shutter 25 rapidly to the state shown in Figs. 6 and 7 makes it possible to record a recording minimum unit called a dot under the condition that the ink 31 is continuously applied pressure by the pressure-applying unit 60. Then, controlling the rest time of the shutter 25 at its each rest position, the apparatus can record dots in various manners. In this case, the control circuit 141 shown in Fig. 5 has a function to manage time, it is very easy to make up such a circuit.

In this embodiment, however, the shutter 25 has two rest positions, if the electrodes 24a to 24h are increased more, the rest positions are also increased. For example, the shutter may have three rest positions so that the ink passing hole of the shutter allows ink to be jetted only at the center rest position. When the shutter is driven and shifts its position in one direction from one end to another end, a dot is recorded without returning of the shutter and recording speed of such apparatus becomes faster than that of the embodiment shown in Fig. 1. In this case, the rest time of the shutter may be also controlled as described above.

Further, it is possible to constitute a shutter which allows ink-jetting during its one-direction shifting between tow rest positions. In this case, it is difficult for the shutter to stop at the position where the ink is jetted through the ink passing hole.

For example, an ink-jetting mode may be set such that the ink is continuously jetted without being cut into droplets corresponding to each one dot respectively. In such case, the shutter is required to stop at the position where the ink passes through the ink passing hole of the shutter. Consequently, the recording quality of the apparatus will be somewhat inferior.

To summarize the various embodiments mentioned above, the embodiment shown in Fig. 1 has no problem when the shutter 25 reciprocates at enough high speed. Comparing the embodiment with another embodiment having three rest positions with respect to number of electrodes, namely number of wires, integration efficiency, both of them are substantially equal.

Moreover, when the pressure-applying unit 60 can be operated in synchronization with recording frequency, the ink 31 will not be jetted through the ink passing hole 25a during the movement of the shutter 25. The piezoelectric device is employed in the present embodiment, other means can be employed as a pressure-creating means instead of the d vice.

The friction produced between the surfaces of shutter 25 and substrate 21 or front wall 28 acts as a factor of preventing the shutter 25 from sliding. Although, since the nitride film 23 and the like reduce the friction the shutter 25 is slideable, a few problems may still remain. However, when the pressure-applying unit 60 is controlled so that the ink 31 is applied pressure in synchronization with the reciprocating of the shutter 25 and the ink droplets are jetted at only the timing in which the ink passing hole 25a of the shutter 25 is aligned with the ink jet port 21a of the substrate 21, such problems of friction are solved considerably, since the shutter 25 is not pushed against the front wall 28. But, in this case, each time the shutter 25 shuts off the ink jet port 21a from ink-jetting, the ink has impact on the shutter 25 and the front wall 28. For the mechanical strength of the shutter 25 and the front wall 28, these prefer to be applied continuous pressure rather than intermittent one. Further, the driving circuit 61 will become complicated and also power supply and the like will become large size for creating the intermittent pressure. From a general point of view, both of them are substantially equal.

According to the present embodiment, as described above, it is easy to vary the rest time of the shutter 25 at its rest position where the ink droplets are allowed to be jetted. That is, the size of a dot is controllable by varying the size (volume) of an ink droplet. Therefore, an area gradation recording can be performed, and especially it is very useful for recording a picture image such that the recording quality will be substantially improved. That means an improvement of roughness with respect to an image quality, and it is very valuable.

As described heretofore, according to the present invention, it is possible to provide an ink recording apparatus which makes it possible for the ink to be designed most suitably, because the ink is jetted and shut under the mechanical control of the shutter 25 which is shifted with applying voltage to the electrodes 24a to 24h, and which can be highly reliable and superior in recording quality.

Next, with reference to Figs. 8a to 8n, the ink recording apparatus of the above-mentioned embodiments will be described in its manufacturing method, wherein, since the method utilizes the one generally used in semiconductor device manufacturing techniques, the description of individual processes will be simplified by omitting the details of common knowledge thereof.

(a) A concave portion 21a as illustrated in Fig. 8a is formed on the surface of the single-crystal silicon substrate 21 by anisotropic etching. As the etching solution, an aqueous solution of potassium hydroxide (KOH) is used. Photoresist is removed by photo-resist stripping using oxygen plasma. The removing of photo-resist is carried out likewise in the following processes.

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(b) The oxide film 22 (SiO_2) is made to grow on the substrate 21, where the oxide film 22 is made grown by depositing a PSG (Phosphor Silicate Glass) layer 33 of a weight ratio of 8% by the method of LPCVD (Low Pressure Chemical Vapor Deposition) at a temperature of approximately 450° C, and the film 22 is etched using a buffered hydrofluoric acid, as shown in Fig. 8b.

(c) The nitride film 23 (Si_3N_4) is deposited on the oxide film 22, subjected to patterning by RIE (reactive-ion-etching). The nitride film 23 in combination with the oxide film 22 makes up an insulating layer, the dielectric breakdown voltage of which is more than 500 V. The nitride film 23 also serves to protect the oxide film 22 dissolved with the buffered hydrofluoric acid.

(d) A PSG layer 33 of a weight ratio of 8% is deposited by the LPCVD method at approximately 450° C, followed by etching using the buffered hydrofluoric acid.

(e) A polycrystalline-silicon layer 34 is entirely deposited at approximately 610 to 630° C by the LPCVD method and shaped as shown in the figures by plasma etching. The polycrystalline-silicon layer 34 forms the electrodes 24a to 24h and the shutter 25. Then, annealing is performed to remove the residual stress. In addition, the polycrystalline-silicon layer 34 may be imparted with electrical conductivity by diffusing phosphorus therewith as required.

(f) An oxide film 35 is made to grow on the polycrystalline-silicon layer 34, where for the oxide film 35 a PSG layer of a weight ratio of 8% may be deposited at approximately 450° C by the LPCVD method. The oxide film 35 will serve as a protection film for the RIE later performed.

(g) The polycrystalline-silicon layer 34 and the oxide film 35 are subjected to patterning by plasma etching as shown in Fig. 8g, thereby shaping into the electrodes 24a to 24h and the shutter 25. In this process, end points are detected with 30% overetching, and annealing are performed to remove the residual stress.

(h) A nitride (Si_3N_4) film 26 is deposited as shown in Fig. 8h, where patterning is performed by the RIE. The nitride film 26 finally forms the above-mentioned nitride film (not shown), serving as a lubricating layer for reducing the friction between the shutter 25 and relevant portions and compensating the brittleness of materials and also as an insulating layer (not shown) for the electrodes 24a to 24h.

(i) A PSG layer 36 of a weight ratio of 8% is entirely deposited by the LPCVD m thod at approximately 450° C.

(j) The PSG lay r 36 is etched using buffered hydrofluoric acid as shown in Fig. 8j.

(k) The PSG layer 36 is subjected to patterning by plasma etching as shown in Fig. 8k. This patterning will enable the fixing of the guide pins 27b, 27c and the front wall 28 (both shown in Fig. 1) to be later formed. The end points are detected with 30% overetching.

(l) A polycrystalline-silicon layer 37 is deposited by the LPCVD method at approximately 610 to 630° C, subjected to patterning by plasma etching as shown in Fig. 8l, thus forming the guide pins 27b, 27c and the front wall 28. Here, annealing is performed to remove the residual stress.

(m) The PSG layers (or oxide films) 33, 36 are dissolved with a buffered hydrofluoric acid to form a movable member into which the polycrystalline-silicon layer 34 and the oxide film 35 are integrated, thereby forming up the shutter 25 as shown in Fig. 1.

(n) The substrate 21 is anisotropically etched from its rear side as shown in Fig. 8n to form the concave portion 21b′ until it is bored through up to the concave portion 21a′ first formed. This allows the ink jet port 21a and the ink sump 21b, as shown in Fig. 2, to be formed.

Through the above processes, the ink recording apparatus of the first embodiment of the present invention can be manufactured. As seen here, the component structures are integrally manufactured using the semiconductor device manufacturing processes, thereby allowing the integrated head to be manufactured very simply and furthermore rendering them high in precision as well as steady in performance. Besides, the integration degree can be substantially increased by arranging the apparatuses crosswise. Accordingly, the ink recording apparatus can be steadily mass-produced which features their remarkably high reliability, light weight and compactness, low cost, quietness, high-speed and high-density recording, and further high precision.

In addition, although in the foregoing first embodiment of the invention the one ink chamber 20 is illustrated such as one ink jet port 21a is formed thereon, the ink jet head is actually formed by integrating the apparatuses in high density, so the ink chamber may have generally a plurality of ink jet ports and shutters.

An example of the ink jet head in which the seven shutters 25 having an ink jet port 21a respectively are integrated in staggered fashion arrangement to one ink chamber (not shown) is shown in Fig. 9. The el ctrodes 24a to 24h are also arranged corresponding to each shutt r 25. Though th other components are not illustrated, one pressure-applying unit and on pump are provided with th head corresponding to the on ink cham-

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ber. With respect to the front wall, a plurality of walls may be formed corresponding to either each shutter or some shutters. Otherwise, one front wall may be formed corresponding to all shutters. As shown in the below of Fig. 9, the condition of the shutter in recording is indicated by a signal "1", and the condition of the shutter in non-recording is indicated by a signal "0". When each shutter 25 is controlled by the signals, a pattern of characters, symbols, and any desired pictures are able to form on a sheet of recording paper. In this case, the control circuits are required corresponding to each of the shutter 25, but such integration of circuit is very easy and does not become burden.

It is possible for the ink recording apparatuses of the first embodiment to be made into the integrated ink jet head described above into even the full size of A4. Further, the arrangement density of them can be enough highly enhanced by arranging them in pattern of staggered fashion.

For example, to maintain the required recording quality at 20 lines/mm of recording density, the diameter of the ink droplet ought to be 50 μm. According to the present invention, the size of ink droplet can be substantially freely set and such diameter is easily set. Then, the printer which employes the ink jet head described above is decidedly superior in high-speed recording performance thereof to the printer according to the prior art.

When the feeding direction of recording paper is set to be along the width of size A4 so that the size A3 is useable, the ink jet head is required a length of about 300 mm. Then, the head needs about 6000 (= 20 x 300) units of the ink recording apparatus of the first embodiment. When the ink jet head takes a second to record a image of size A4 under such condition that the longitudinal recording density is equal to the lateral one, each dot must be recorded within 250 micro seconds. That is, the frequency of the shutter 25 is 4KHz. Such frequency, however, is enough attained even by heating elements, the heating elements have various problems as described before. While, if a serial recording head included 80 ink jet heads recorded same amount of dots within a same period, traversing the recording paper along longitudinal direction of size A4, it should take 3.3 micro seconds to record a dot even if the reversing time of the head were 0 second. The frequency of a pressure-creating means of the ink jet head corresponding to such recording speed of the serial recording head is just attained by piezoelectric elements. But the piezoelectric elements have various problems described before, and not useable for the serial recording head. It means that the ink recording apparatus according to the present invention has very high potentiality.

The second embodiment of the invention can be arranged as shown in Figs. 10 to 13, wherein a single-crystal silicon substrate 41 has an ink jet port 41a provided in the center thereof and an ink sump 41b provided on its side adjoining an ink chamber 40. The ink jet port 41a is formed as bored from the ink sump 41b through an oxide film 42 and a nitride film 43. Electrodes 44a to 44e formed of polycrystalline-silicon, the wiring of which is omitted in the figures, each have on their surfaces a nitride film formed as an insulating layer (not shown). A shutter 45 formed of polycrystalline-silicon has an ink passing hole 45a provided in its center thereof. On the surfaces of the shutter 45 except the underside thereof there is formed nitride films (not shown) as lubricating layers. Shaft 47 is formed also of polycrystalline-silicon, and supports the shutter 45 rotatably and also holds the shutter 45 by the upper flanged portion 47a thereof. On the other hand, the ink chamber 40 and the ink sump 41b are charged with ink 51 composed of insulating material.

The component parts shown in Figs. 10 to 13, like the first embodiment, are integrally manufactured onto the substrate 41 using semiconductor device manufacturing processes including lithography and etching. The result, also like the first embodiment, is that the component parts are substantially compact in size, light in weight, and of high precision, comparable to semiconductor products. Therefore, an ink jet head in which the ink recording apparatuses of the present embodiment are integrated is manufactured without difficulty, and it is possible to select the arrangement pattern of the apparatus and/or the arrangement density of them in their integration.

The control circuit for the shutter 45 and the pressure-applying unit for the ink 51 are the same as the first embodiment.

Now the ink recording apparatus arranged as stated above will be explained with respect to its operation. The state thereof shown in Figs. 10 and 11 is such that a voltage of several times 10 V or so is applied to the electrodes 44a and 44c. In this state, the shutter 45 is stably positioned as shown in the figures with its ends 45p and 45g sucked up by virtue of electrostatic attracting force acting between the ends and the surfaces of the electrodes 44a and 44c, where the ink jet port 41a of the substrate 41 is shut off by the shutter 45, so that the ink 51 charged in the ink sump 41b can not be jetted out through the ink passing hole 45a even if the ink is jetted through the ink jet port 41a due to the pressure applied to the ink. At this point of state of the apparatus, even if a sheet of recording pap r is set at the outside of the shutter 45, the shutter 25 does not allow the ink droplets to record any patterns of characters, symbols, and the like.

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Next, the ink recording apparatus will be described in its states in which the shutter 45 has moved away from the position shown in Fig. 10. In this case, the control circuit judges that the apparatus completed the ink-jetting operation according to an input signal delivered from the apparatus main body via the input terminal, changing the condition of the switches with a result such that the applied voltage is changed from the electrodes 44a and 44c to the electrodes 44b and 44d. In this case, as shown in Fig. 12, the shutter 45 is stably positioned in rest as having rotated about the shaft 47 in a clockwise direction from the position shown in Fig. 10 with its ends 45p and 45g sucked up by virtue of electrostatic attracting force acting between the ends and the surfaces of the electrodes 44d and 44d, where the ink passing hole 45a of the shutter 45 is aligned with the ink jet port 41a. Then, due to the pressure created within the ink chamber 40, the ink 51 charged in the ink sump 41b passes through the ink jet port 41a and ink passing hole 45a of the shutter 25, thus making ink droplets (not shown) to be jetted out.

At this point of the state of the apparatus, setting recording paper at the outside of the shutter 45 allows the ink droplets to record any patterns of characters, symbols, and the like.

Succeedingly to the above-mentioned state, when the applied voltage is changed again from the electrodes 44b and 44d to the electrodes 44c and 44e. In this case, as shown in Fig. 13, the shutter 45 is stably positioned in rest as having rotated about the shaft 47 in a clockwise direction from the position shown in Fig. 12 with its ends 45p and 45g sucked up by virtue of electrostatic attracting force acting between the ends and the surfaces of the electrodes 44c and 44e, where the shutter 45 shuts again the ink jet port 41a. At this point of state of the apparatus, the shutter 25 does not allow the ink droplets to record any patterns of characters, symbols, and the like.

Since the second embodiment is the same as the variation of the first embodiment having three rest positions of the shutter in operation, the second embodiment can perform the area gradation recording, too.

As described heretofore, according to the second embodiment of the present invention, like as the first embodiment, it is possible to provide an ink recording apparatus which can control the jetting and shutting of the ink droplets under the mechanical control of the shutter 45 which is rotated with applying voltage to the electrodes 44a to 44e, and which can be highly reliable and sup rior in recording quality. Further, the second embodiment may be faster than the first embodiment in the recording speed, and can be modified to an ink recording apparatus which needs neither heating elements nor piezoelectric elements (excepting means for applying pressure to whole of the ink chamber) in the ink chamber when the shutter 45 is driven with responding to recording signals.

In addition, with respect to the second embodiment, the front wall and protection plate are not mentioned in the explanation thereof, these elements can be easily formed as necessary. In the first and second embodiments, the electrostatic attracting force is, however, used as the driving force for the shutter, the other means of course may be used. Further, the shape of the ink jet port is not required to be a circle, for example, the ink jet port may be a slit which cooperates with the ink passing hole in forming the ink droplets.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

Claims

1. An ink recording apparatus comprising:
an ink chamber (20) for reserving ink;
an ink jet port (21a) provided to said ink chamber (20);
pressure-applying means (60, 61) for applying pressure to the ink in said ink chamber (20);
a shutter (25) provided in the vicinity of said ink jet port (21a), said shutter (25) being movable between a shut-off position for preventing ink from being jetted out after passing through said ink jet port (21a) and a passing position for allowing ink to be jetted through; and
shutter driving means (24a to 24h, 141 to 146) for driving said shutter (25) in response to recording signals.

2. An ink recording apparatus comprising:
an ink chamber (20) for reserving ink;
an ink jet port (21a) provided to said ink chamber (20);
pressure-applying means (60, 61) for applying pressure to the ink in said ink chamber (20);
a shutter (25) provided in the vicinity of said ink jet port (21a) and outside of said ink chamber (20), said shutter (25) being movable between a shut-off position for preventing ink from being jetted out after passing through said ink jet port (21a) and a passing position for allowing ink to pass through;
shutter driving means (24a to 24h, 141 to 146) for driving said shutter (25) in response to recording signals; and
a wall (28) provided outside of said shutter (25) for

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covering an ext rnal surface of said shutter (25).

3. An ink recording apparatus as claimed in claim 1, wher in a plurality of said ink jet ports (21a) and a plurality of said shutters (25) are corresponding to one said ink chamber (20).

4. An ink recording apparatus as claimed in claim 1, wherein said pressure-applying means (60, 61) comprises first control means (61) for controlling pressure-creating timing so that said pressure is intermittently created in synchronization with timing at which said shutter (25) is in its rest positions.

5. An ink recording apparatus as claimed in claim 1, wherein said pressure-applying means (60, 61) includes a piezoelectric element (60a).

6. An ink recording apparatus as claimed in claim 1, further comprising ink recovering means (28b, 62) for recovering ink shut off by said shutter (25) into said ink chamber (20).

7. An ink recording apparatus as claimed in claim 1, wherein said shutter driving means (24a to 24h, 141 to 146) comprises second control means (141) for controlling a rest time of said shutter (25) being in said passing position and in said shut-off position respectively.

8. An ink recording apparatus as claimed in claim 1, wherein said shutter (25) is formed of a thin film, said shutter driving means (24a to 24h, 141 to 146) comprising:

electrodes (24a to 24h) provided in correspondence to each of said shut-off position and passing position for said shutter(25);

a power supply (146) for applying voltage to said electrodes (24a to 24h); and

a control circuit (141), whereby said shutter (25) is driven by virtue of electrostatic attracting force acting between the surfaces of said electrodes (24a to 24h) and the surface of said shutter (25).

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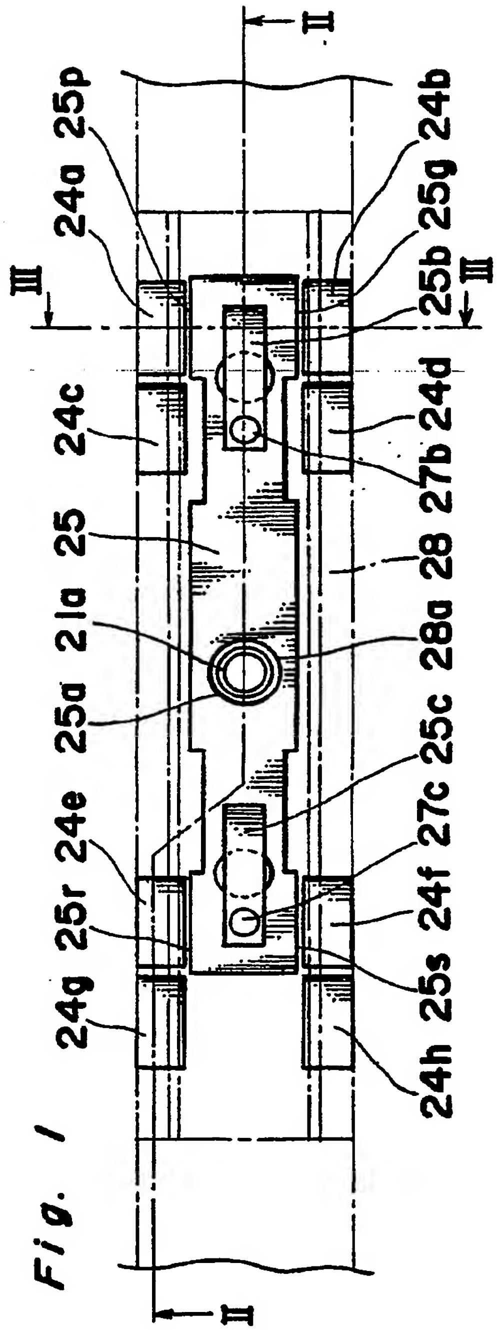
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24c
25
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25a
24e
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24g
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25c
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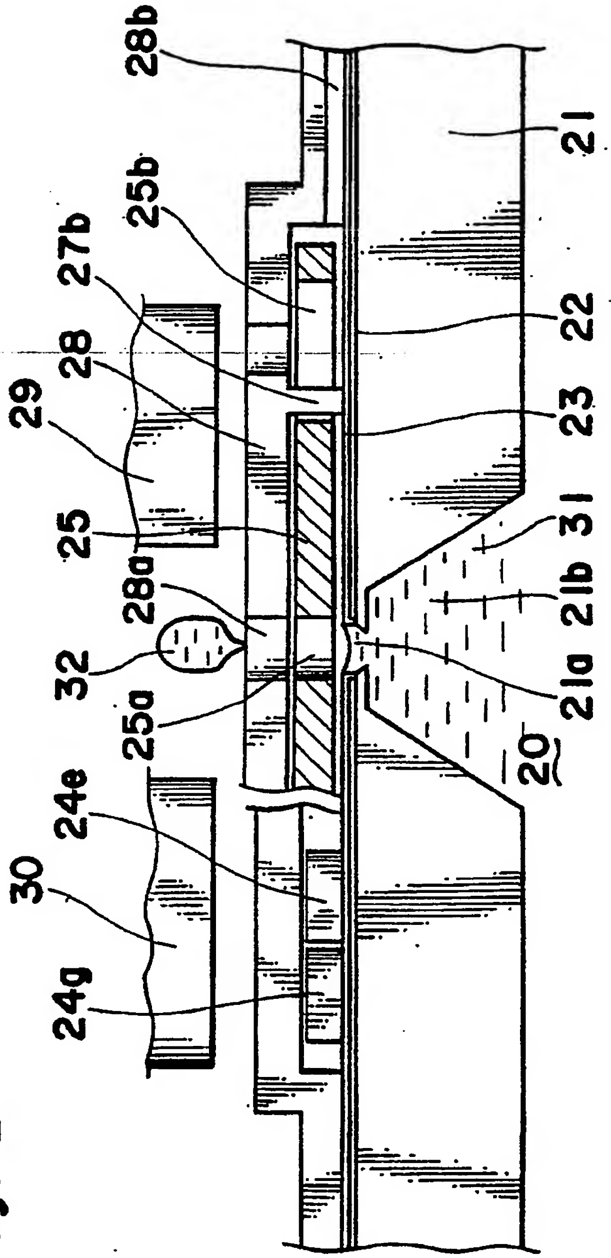
24f
25s
24h
II

Fig. 1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25b
27b
28
29
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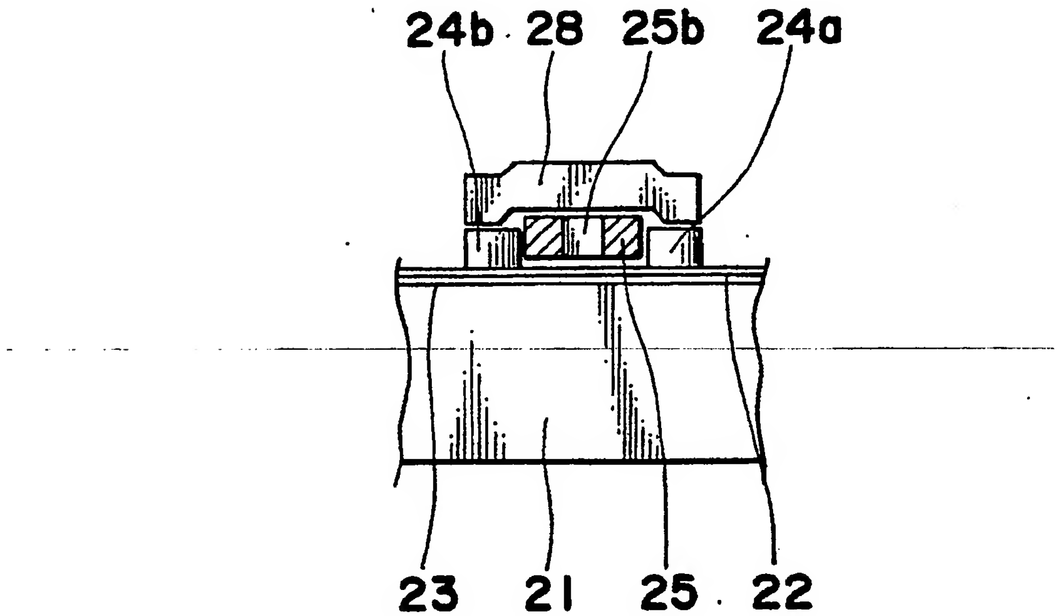
21a
20

Fig. 2

Fig. 3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24a
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25
22

Fig. 4

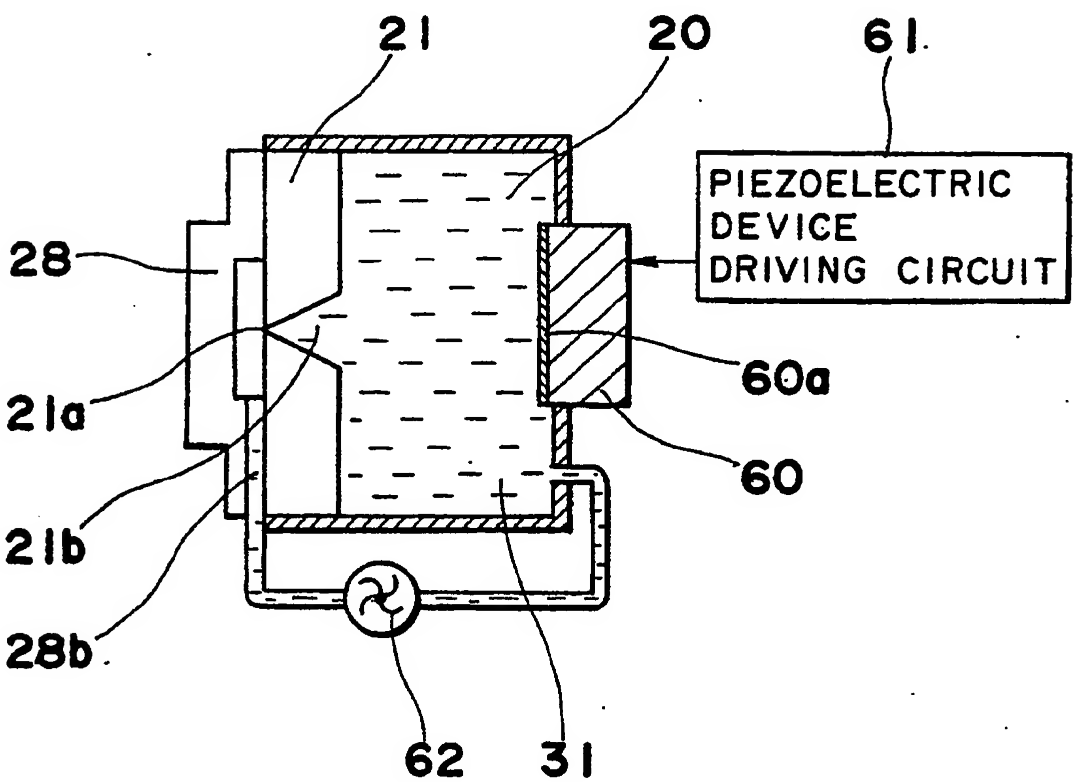

21
20
61
PIEZOELECTRIC DEVICE DRIVING CIRCUIT
28
21a
21b
28b
60a
60
62
31

Fig. 5

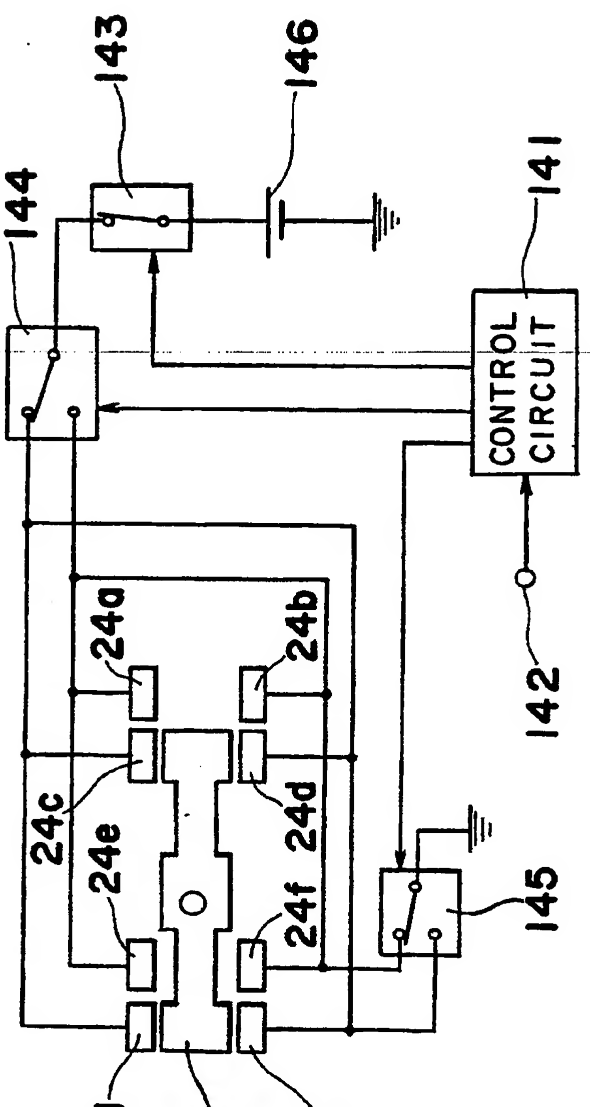
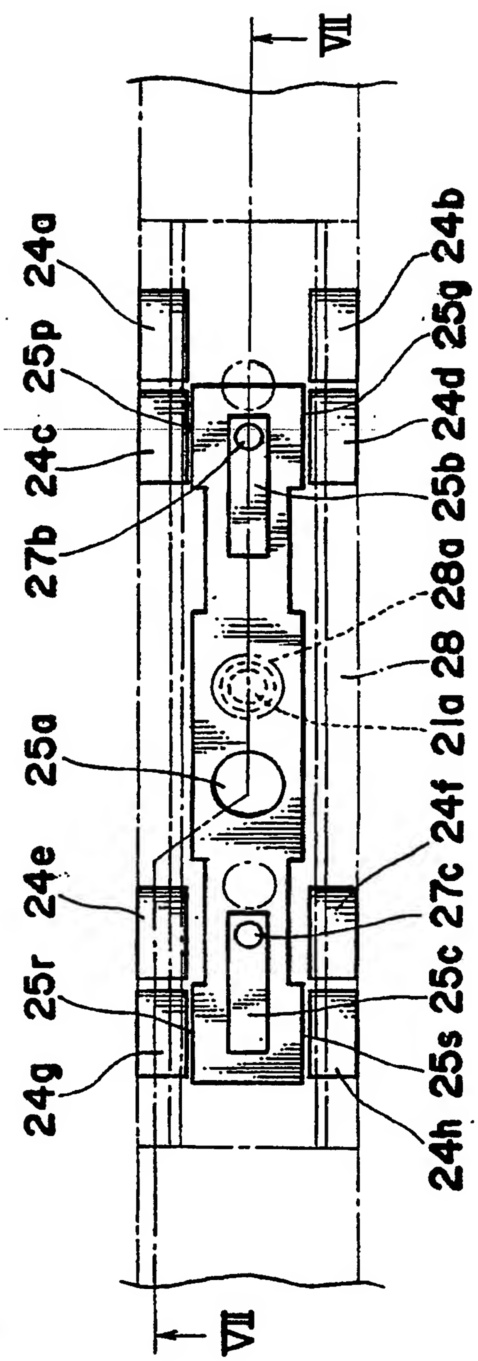

144
143
146
141
CONTROL CIRCUIT
142
145
24a
24b
24c
24d
24e
24f
24g
25
24h

Fig. 6


VII
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25r
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25c
25s
24h
VII

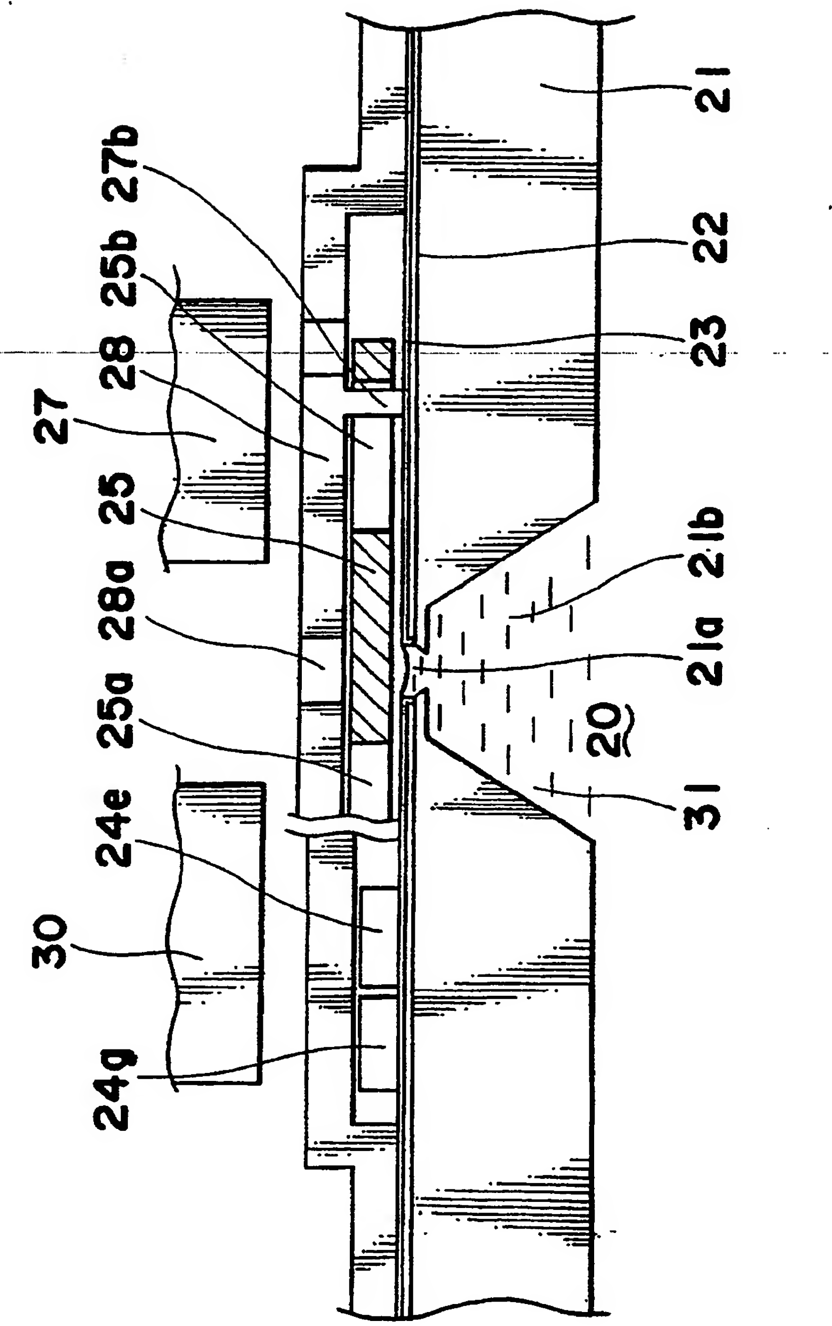

Fig. 7

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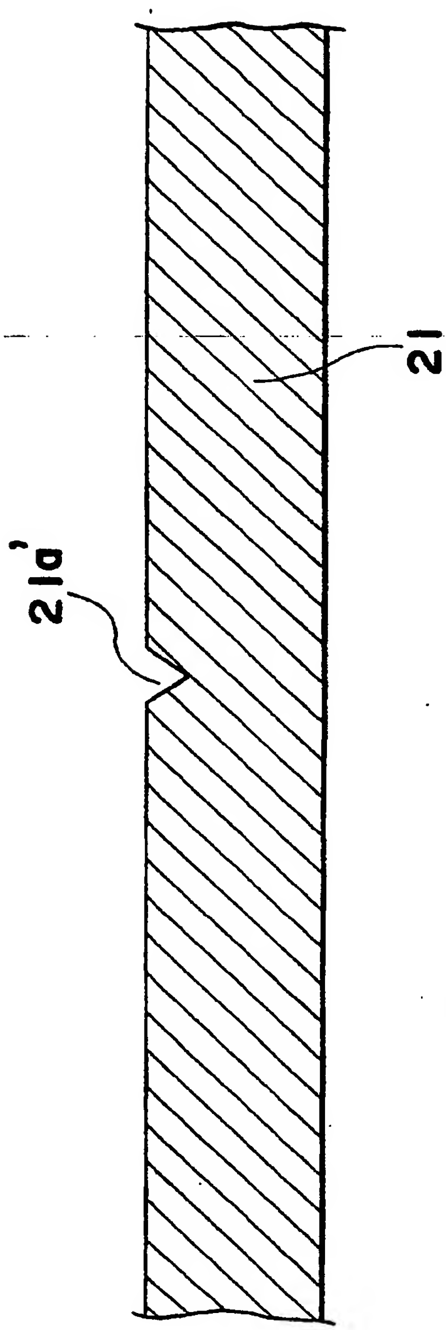

Fig. 8a

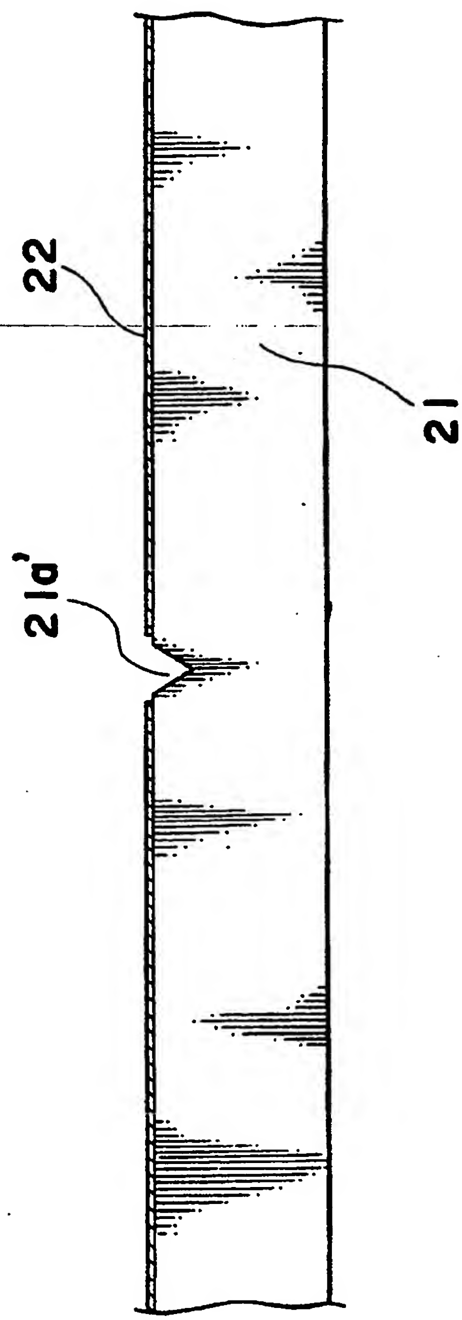

Fig. 8b

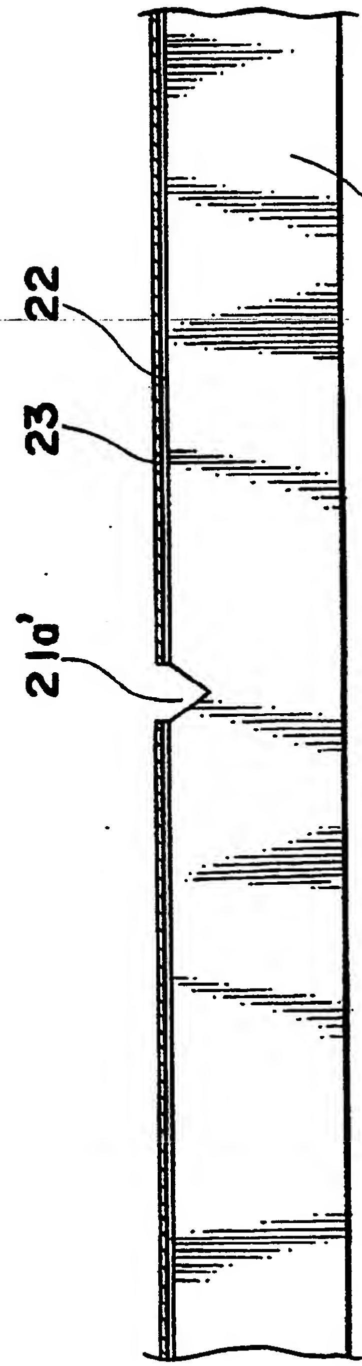

Fig. 8c

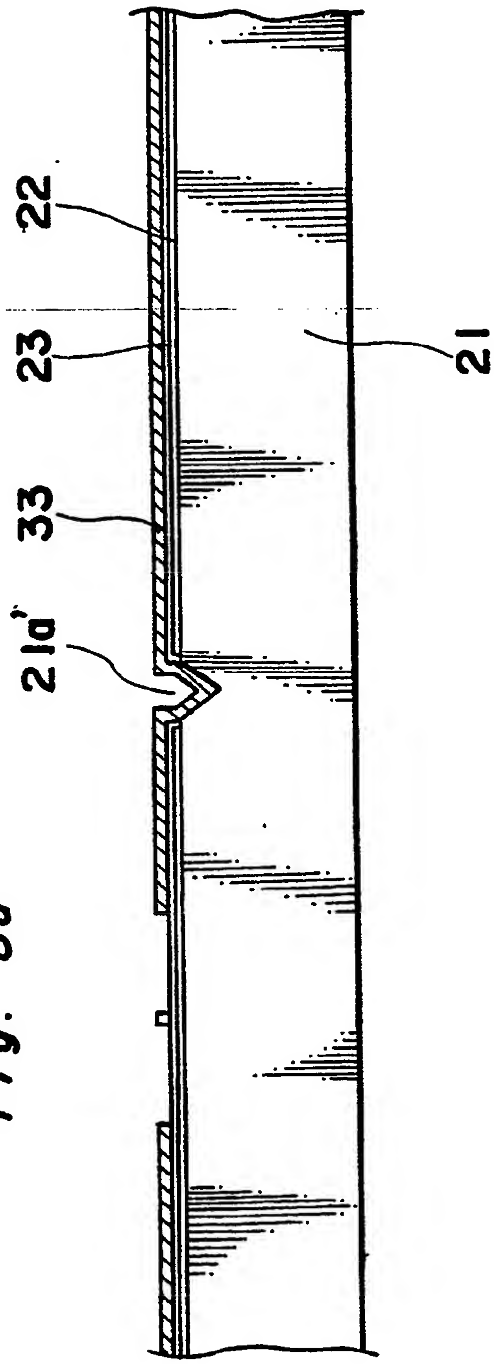

Fig. 8d

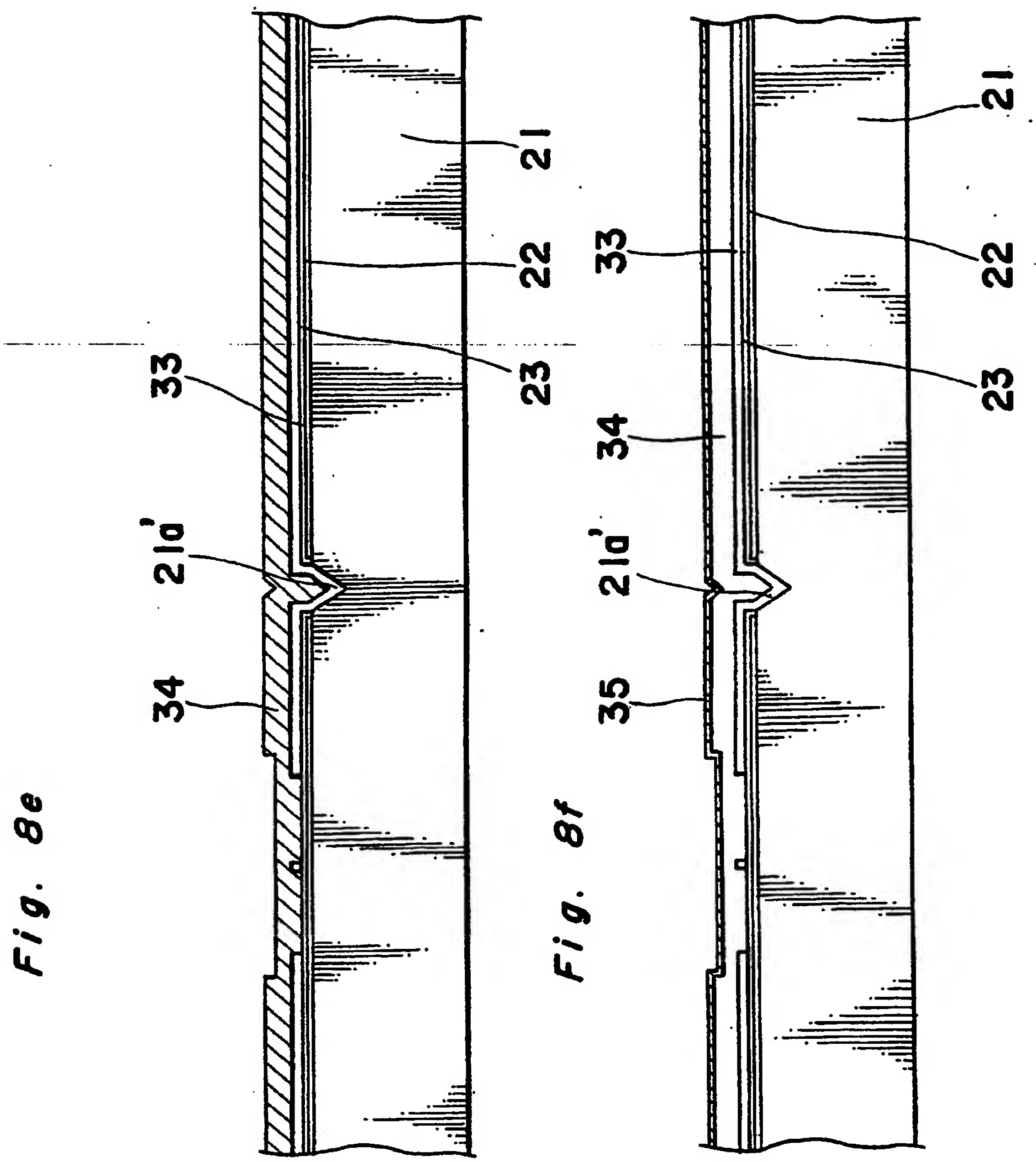

Fig. 8e

Fig. 8f

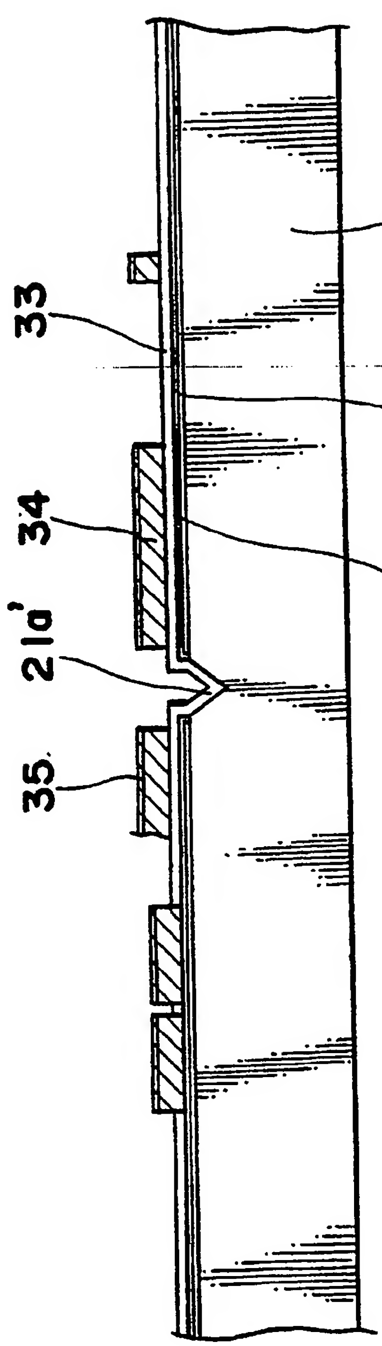

Fig. 8g

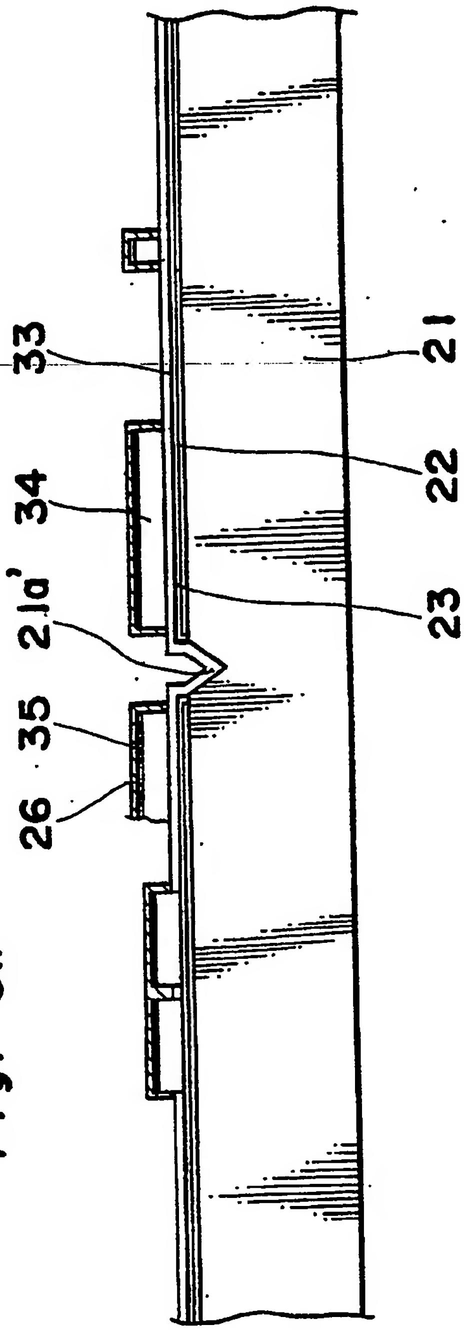

Fig. 8h

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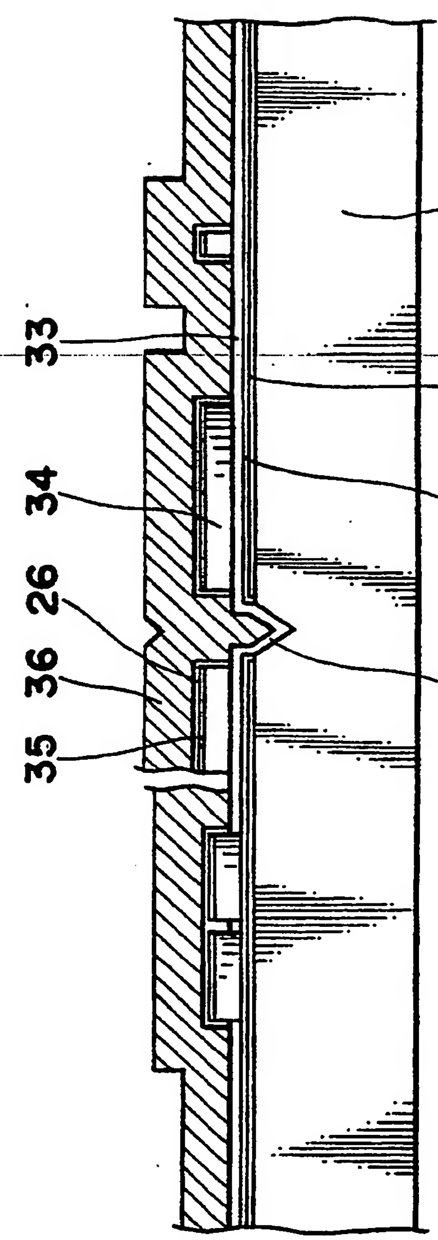

Fig. 8i

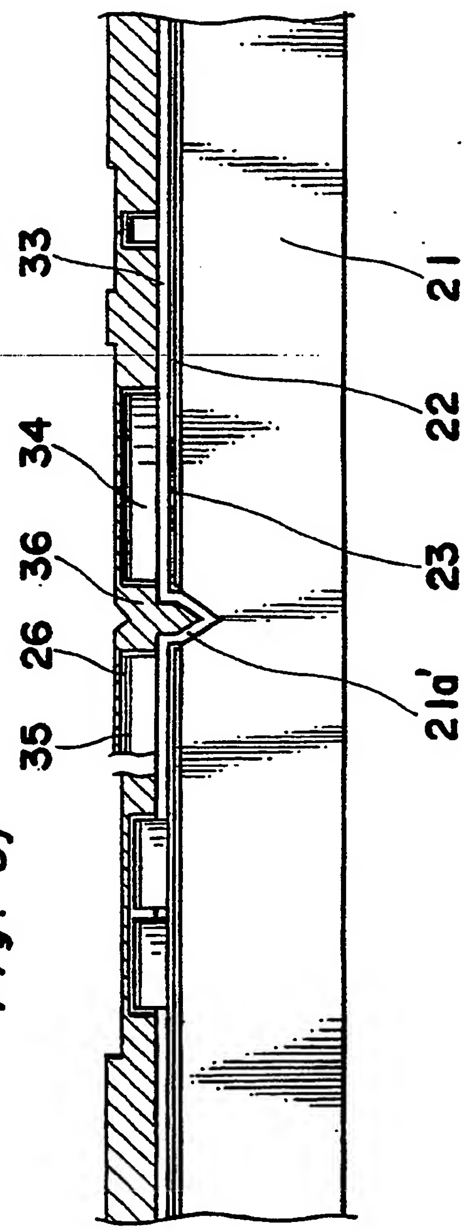

Fig. 8j

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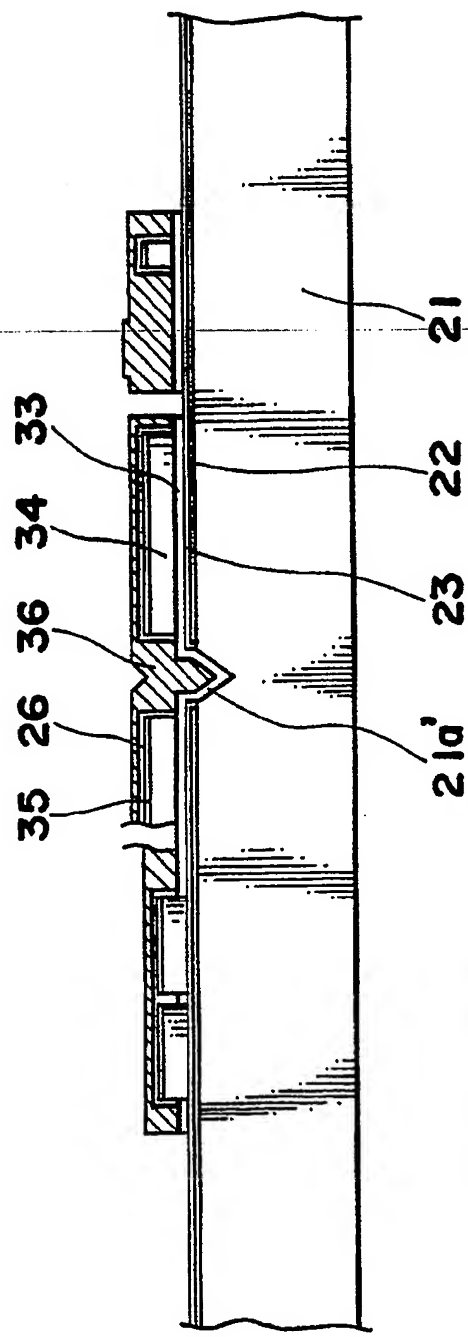

Fig. 8k

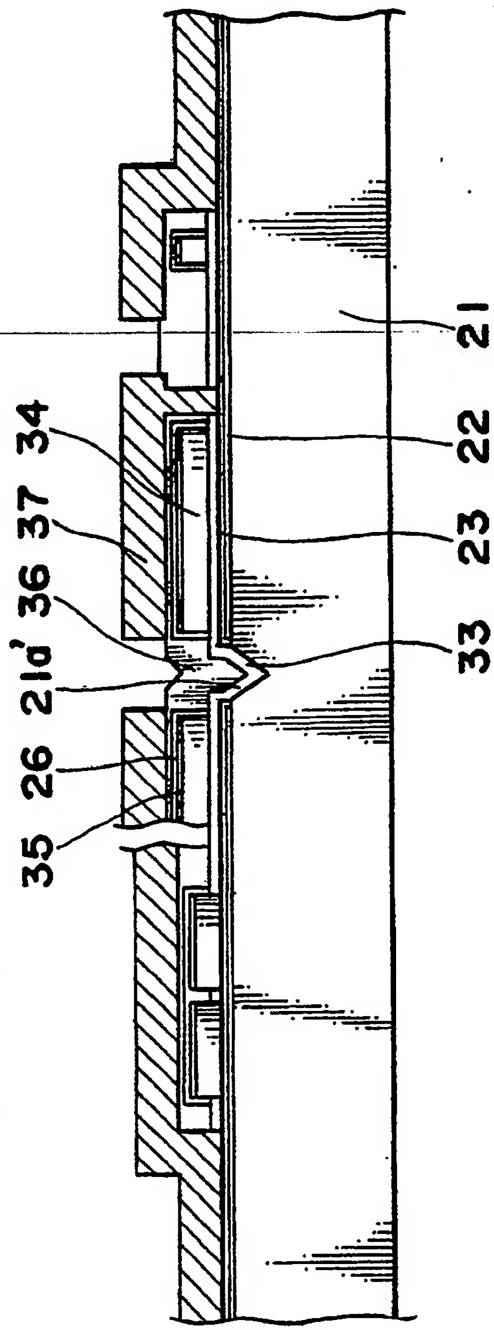

Fig. 8ℓ

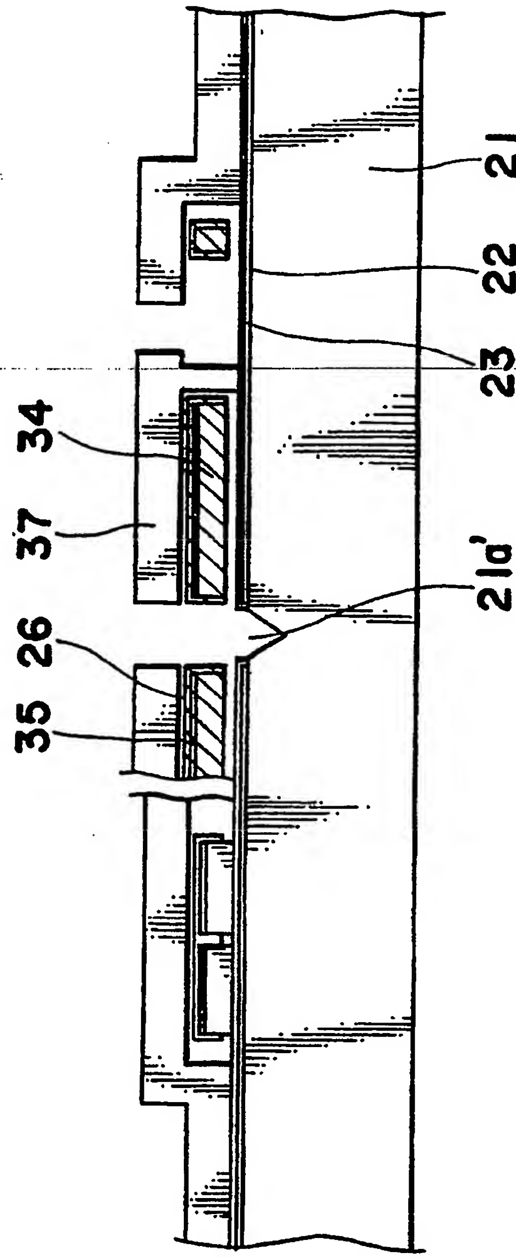

Fig. 8m

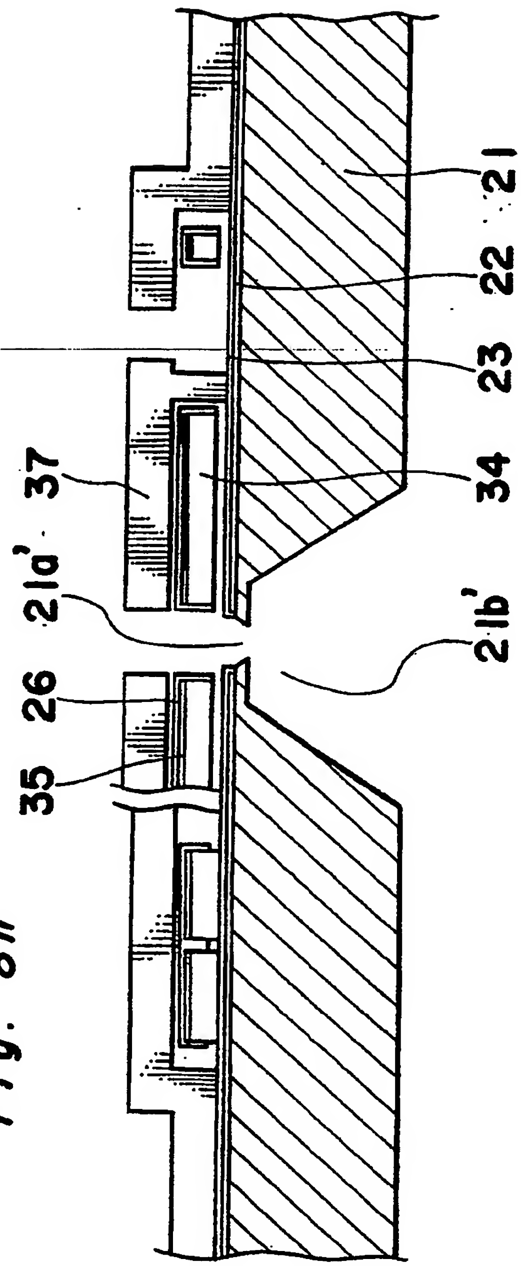

Fig. 8n

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Fig. 9

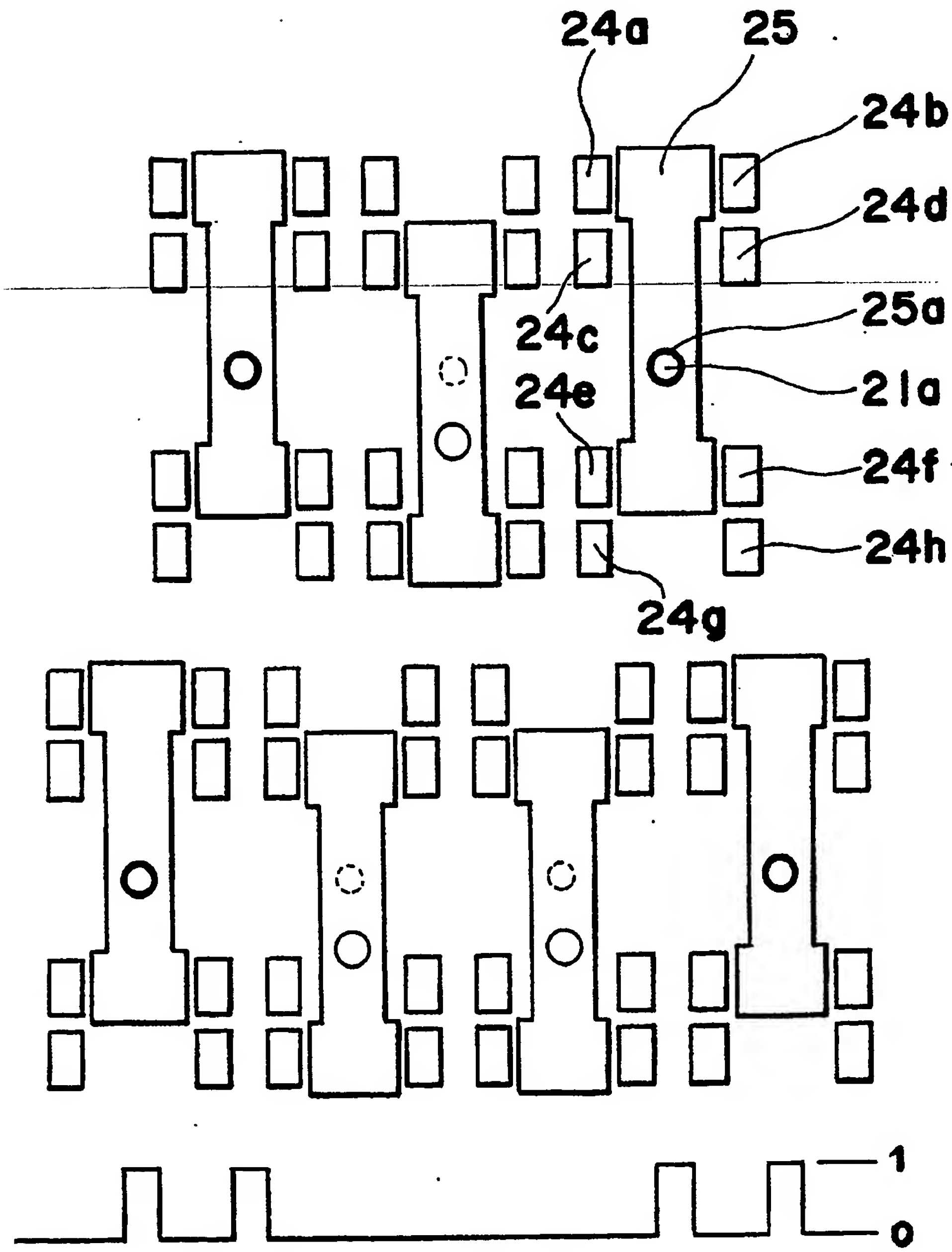

Fig. 10

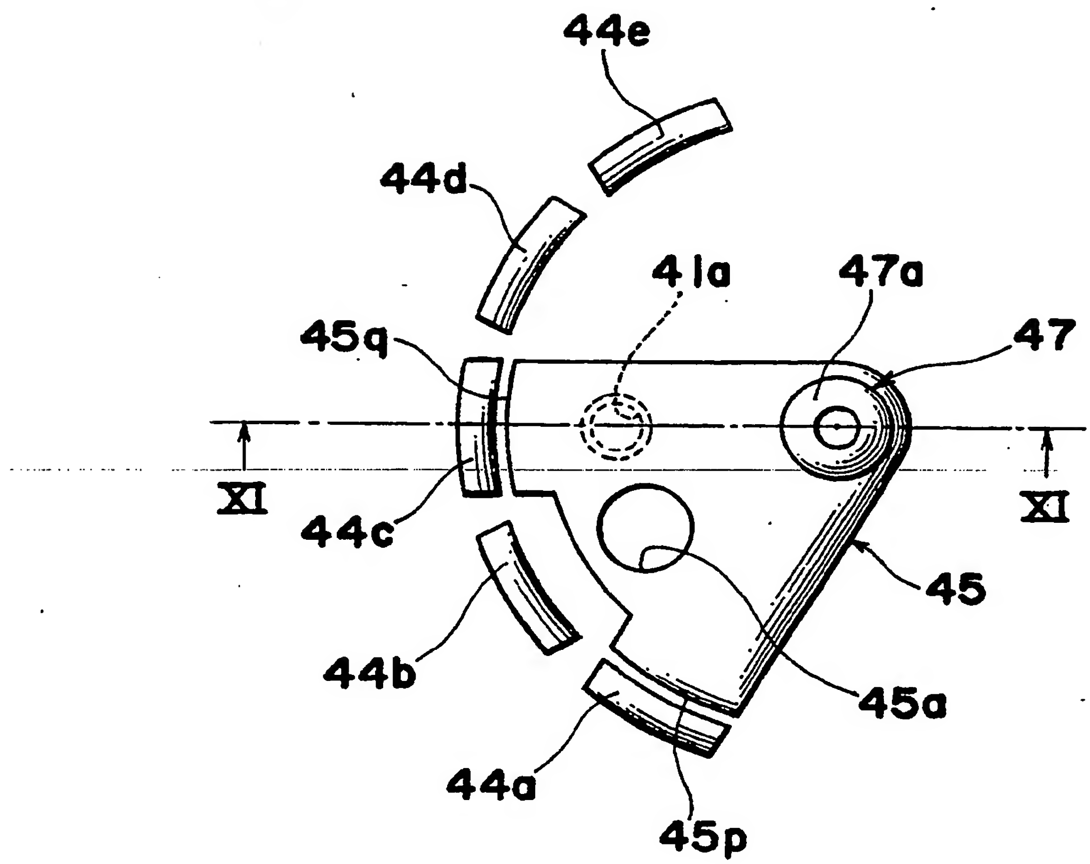

Fig. 11

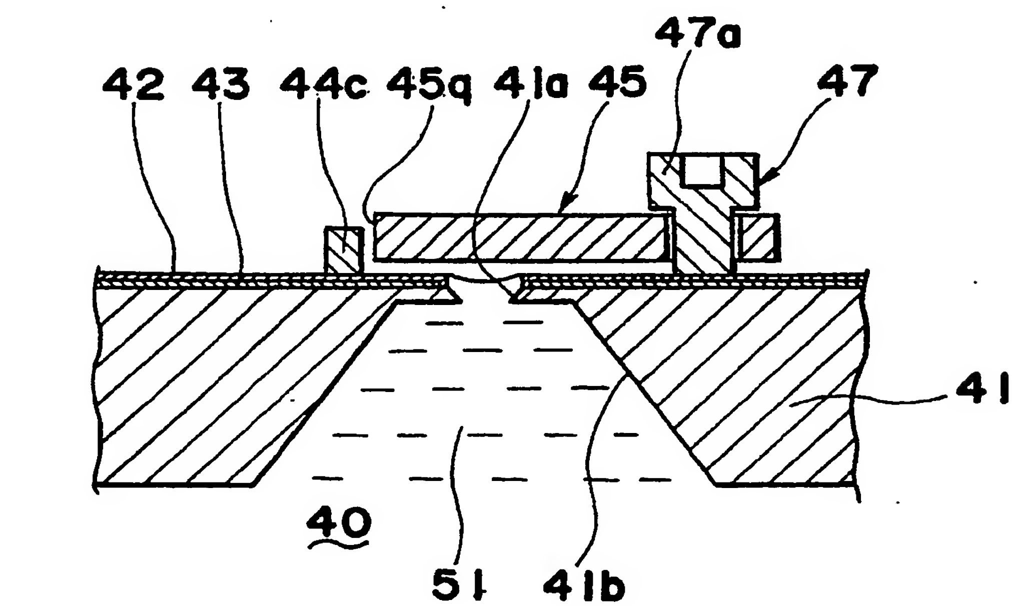

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Fig. 12

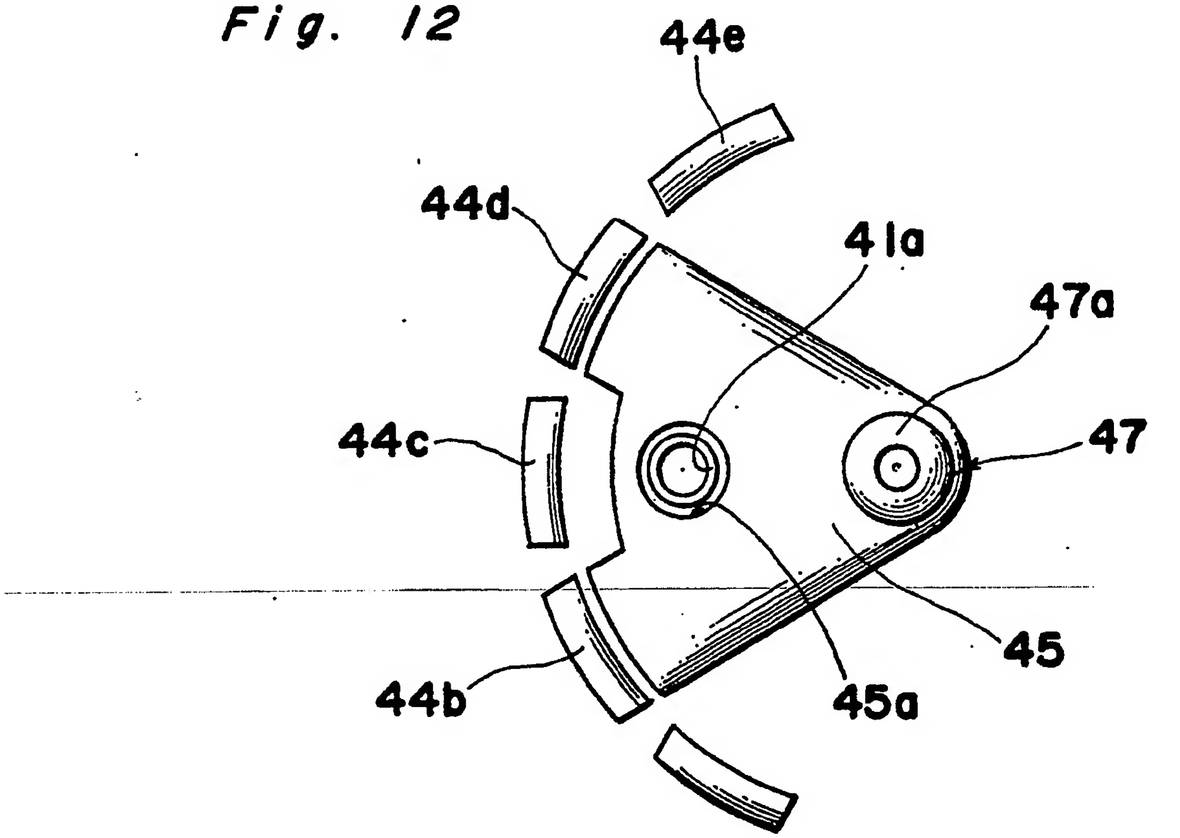

Fig. 13

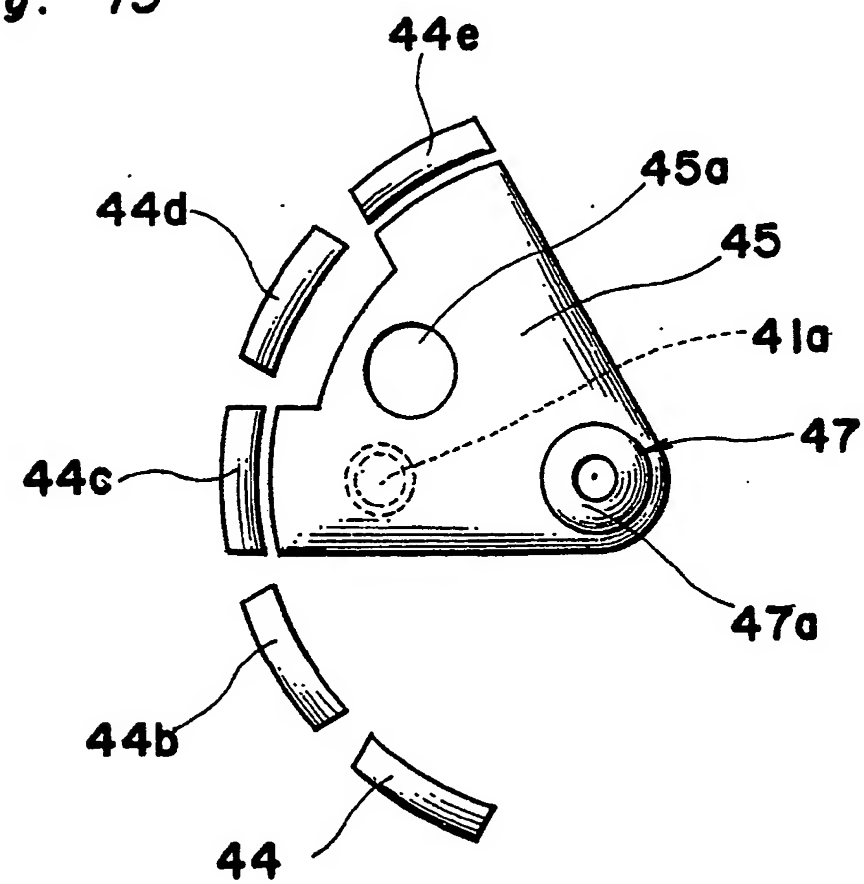

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Fig. 14 PRIOR ART

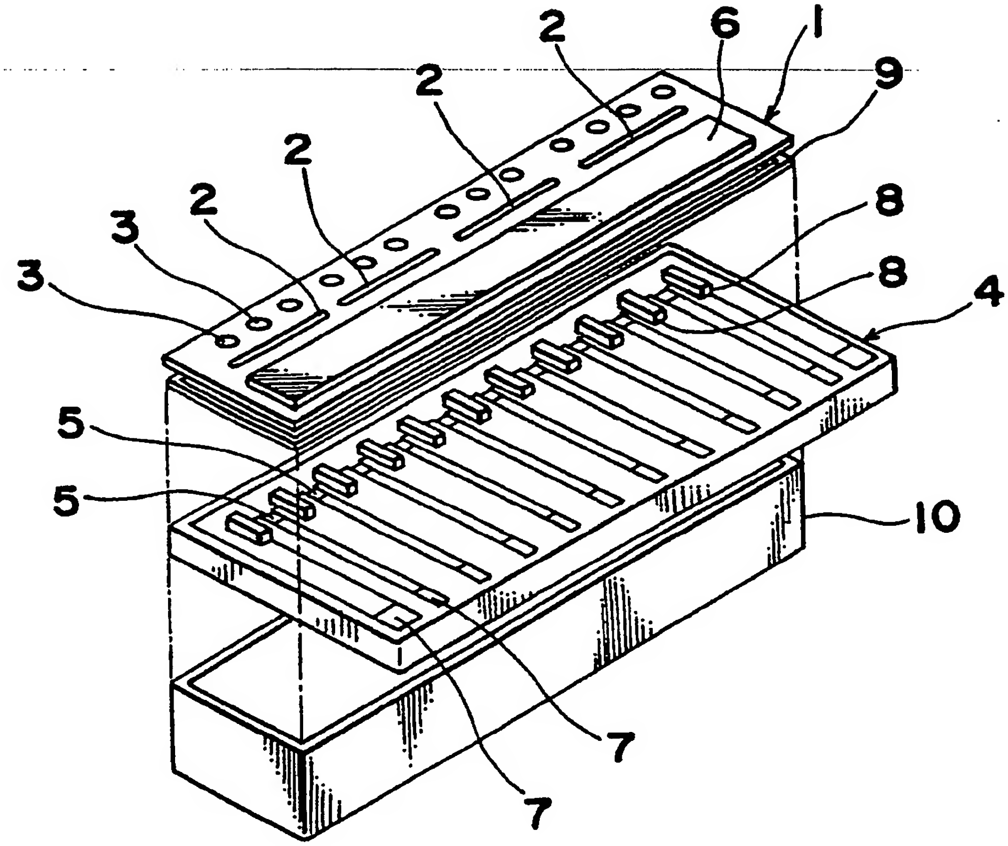

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Fig. 15a
PRIOR ART

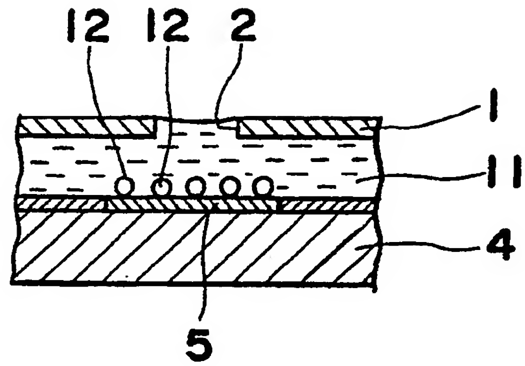


Fig. 15b
PRIOR ART

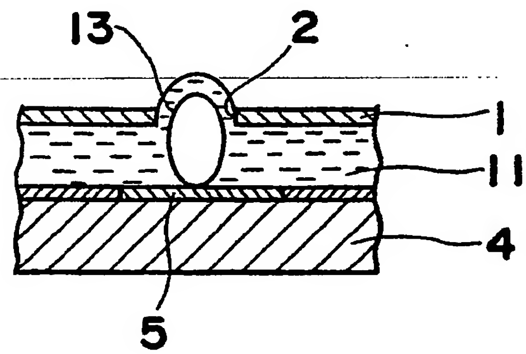


Fig. 15c
PRIOR ART

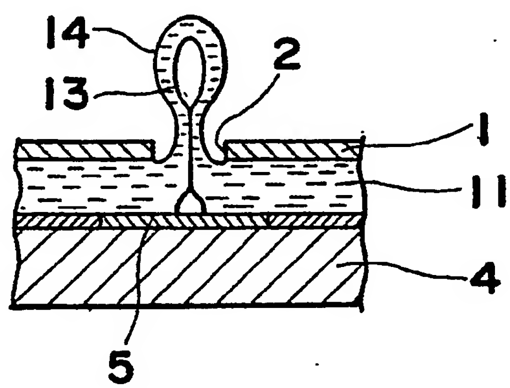
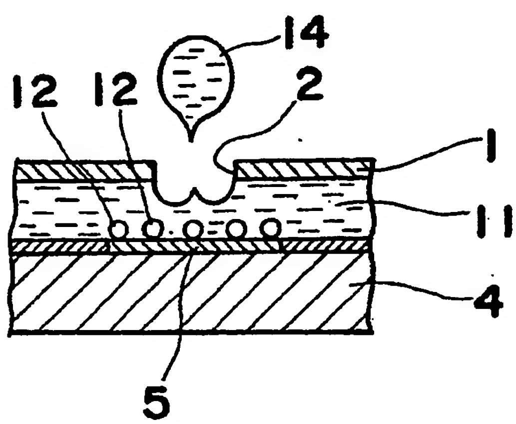


Fig. 15d
PRIOR ART



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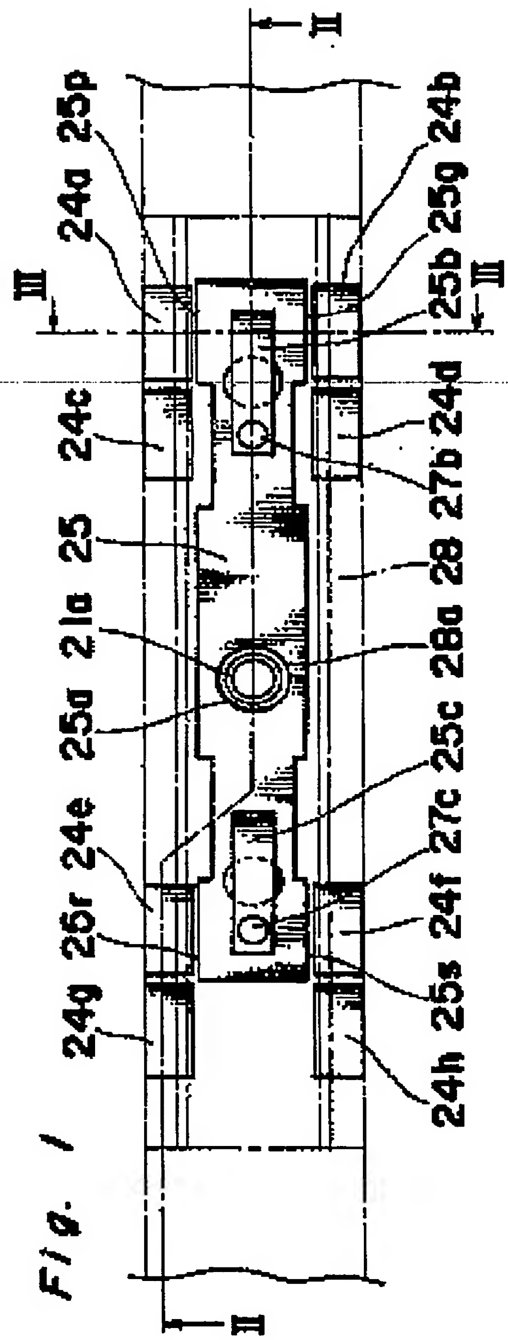
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24h

Fig. 1

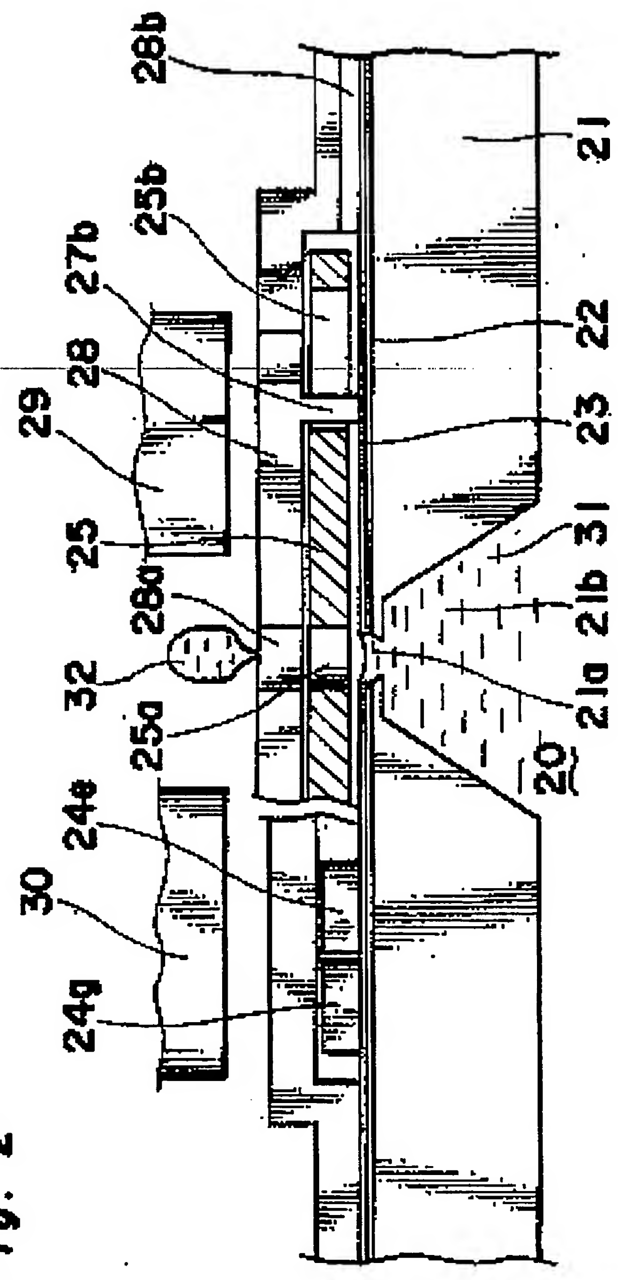
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Fig. 2

Fig. 3

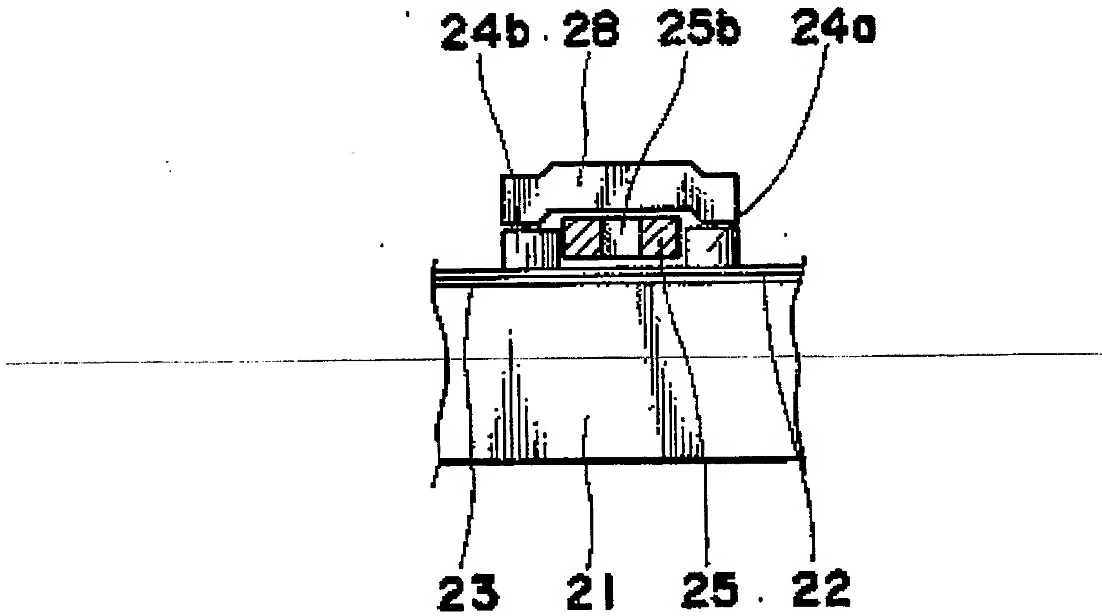
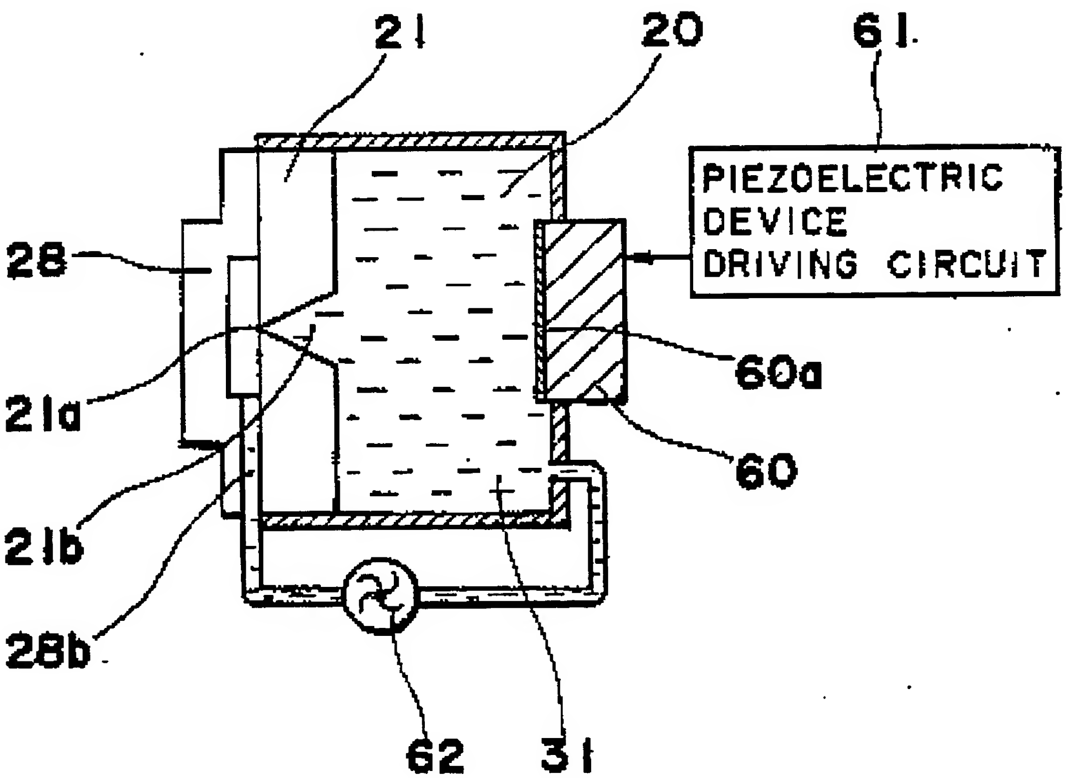


Fig. 4



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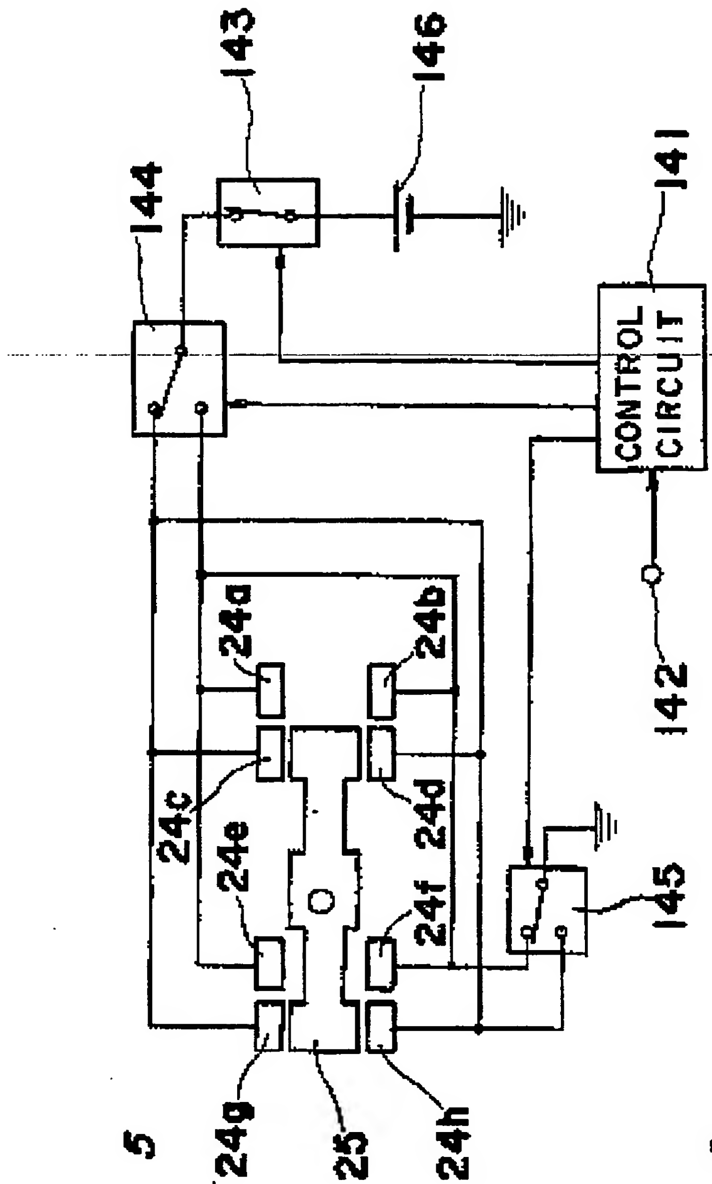

Fig. 5

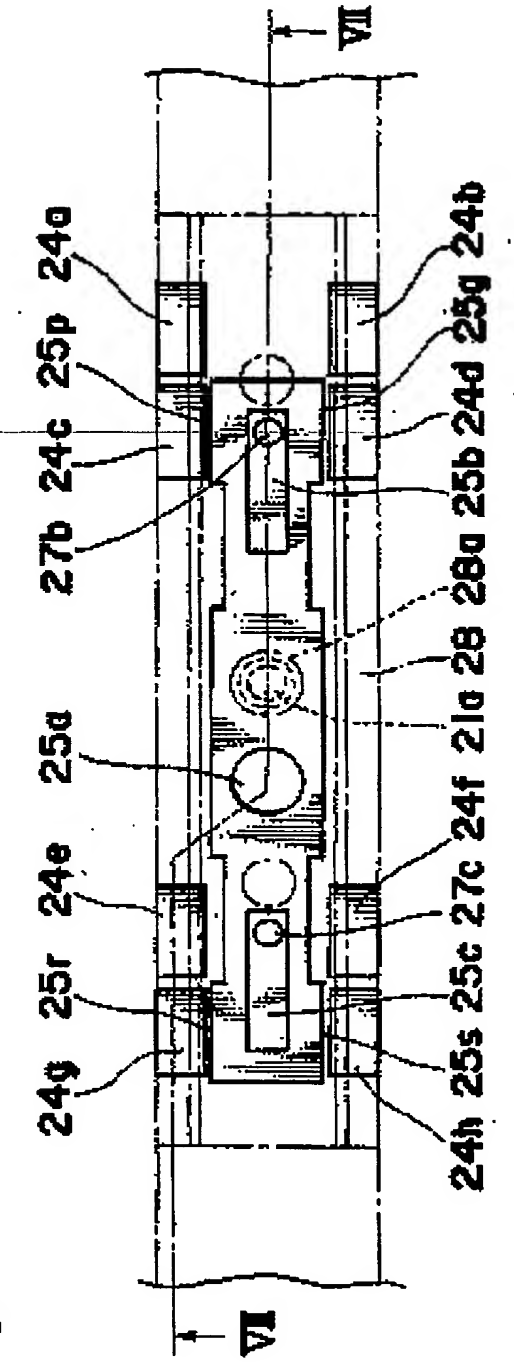

Fig. 6

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Fig. 7

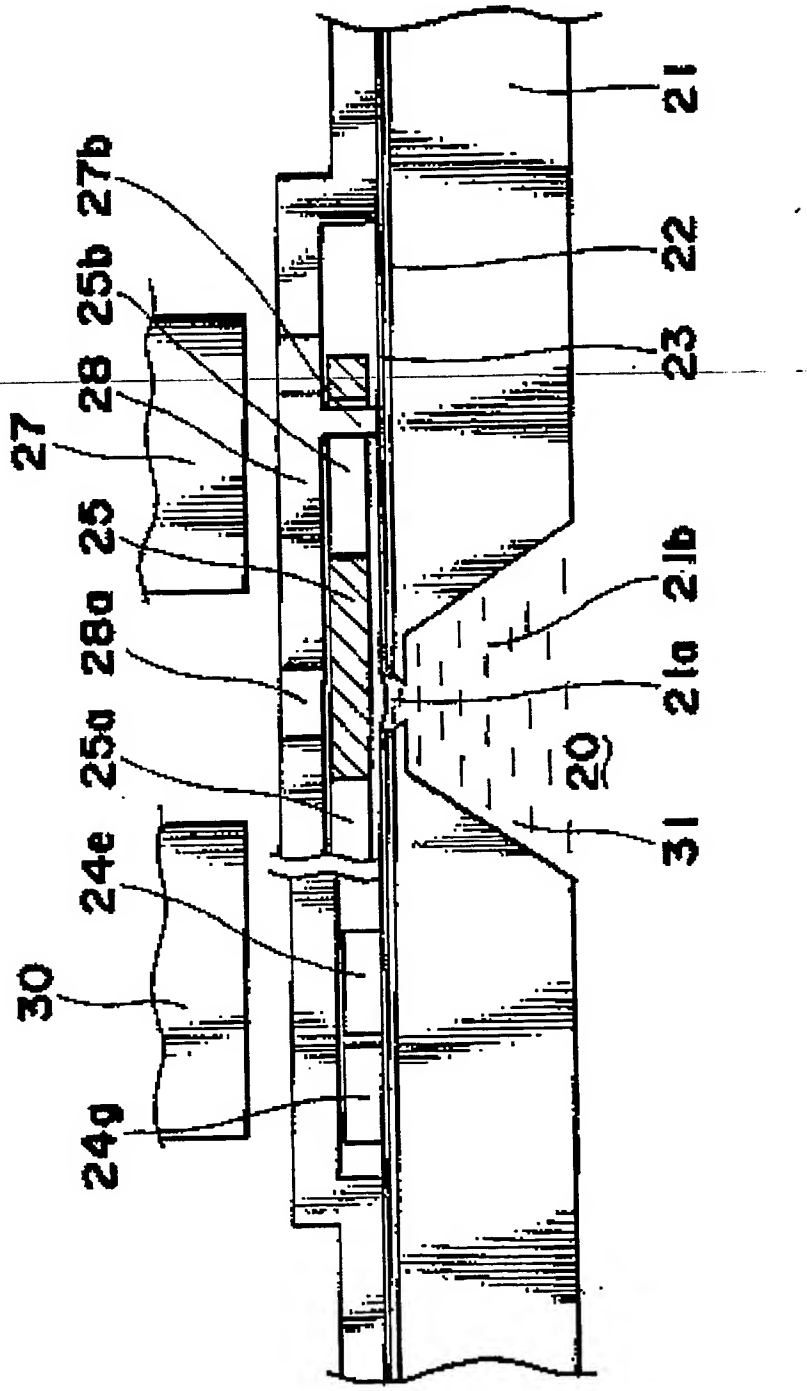

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Fig. 8a

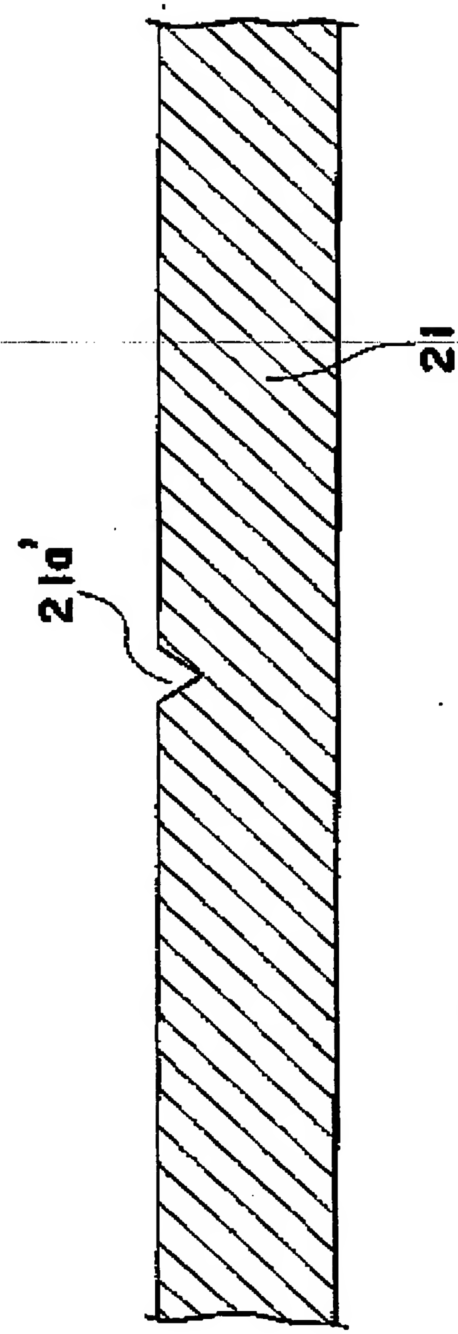
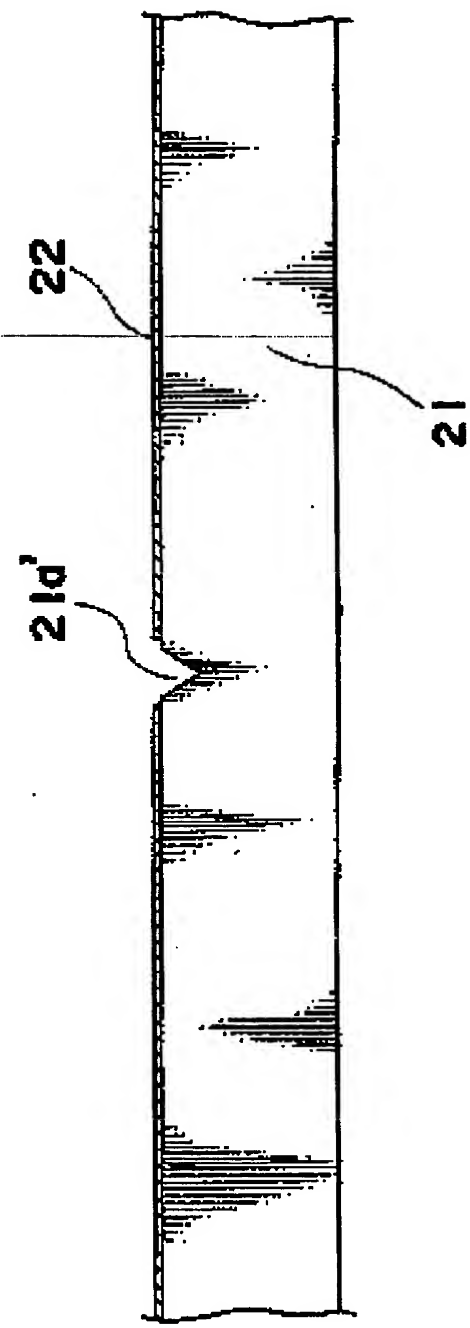


Fig. 8b



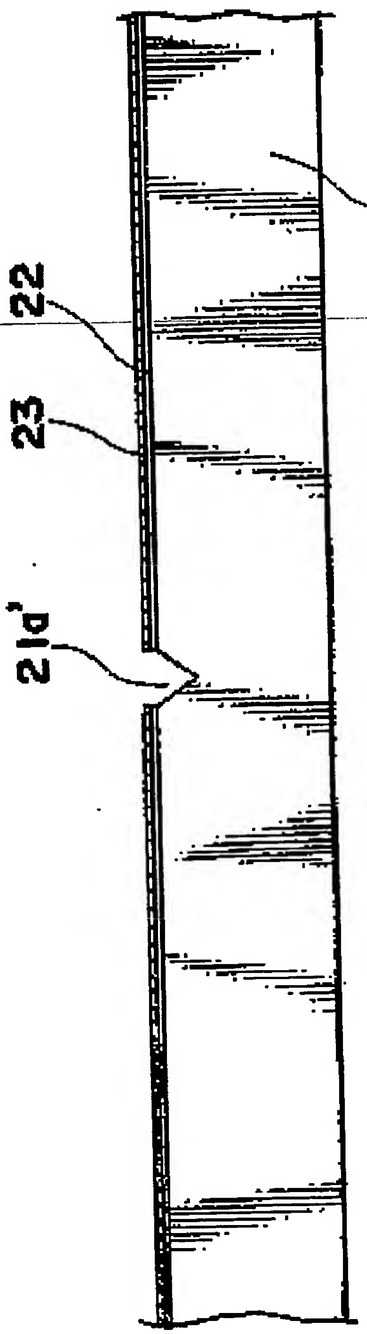


Fig. 8c

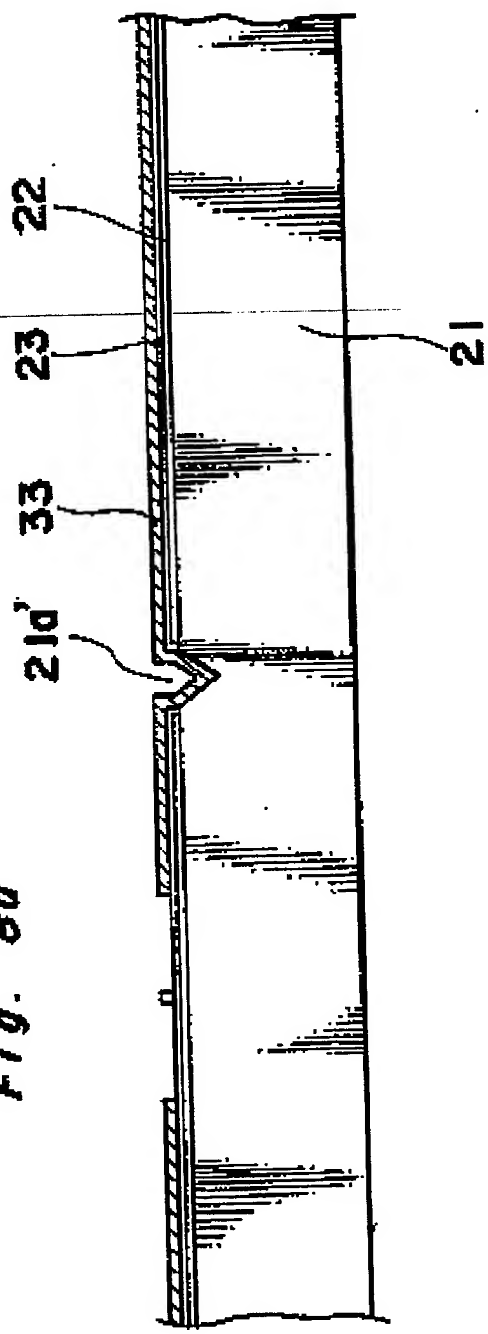


Fig. 8d

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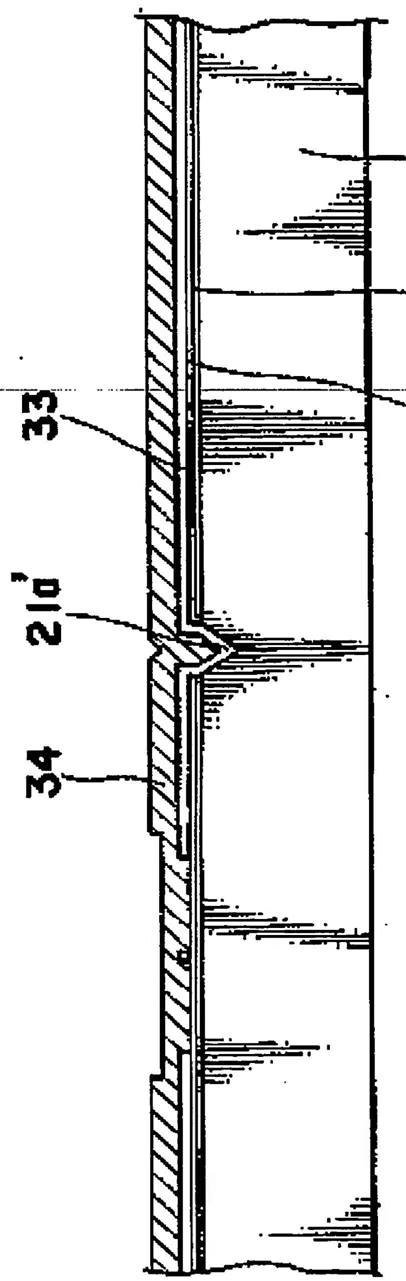

Fig. 8e

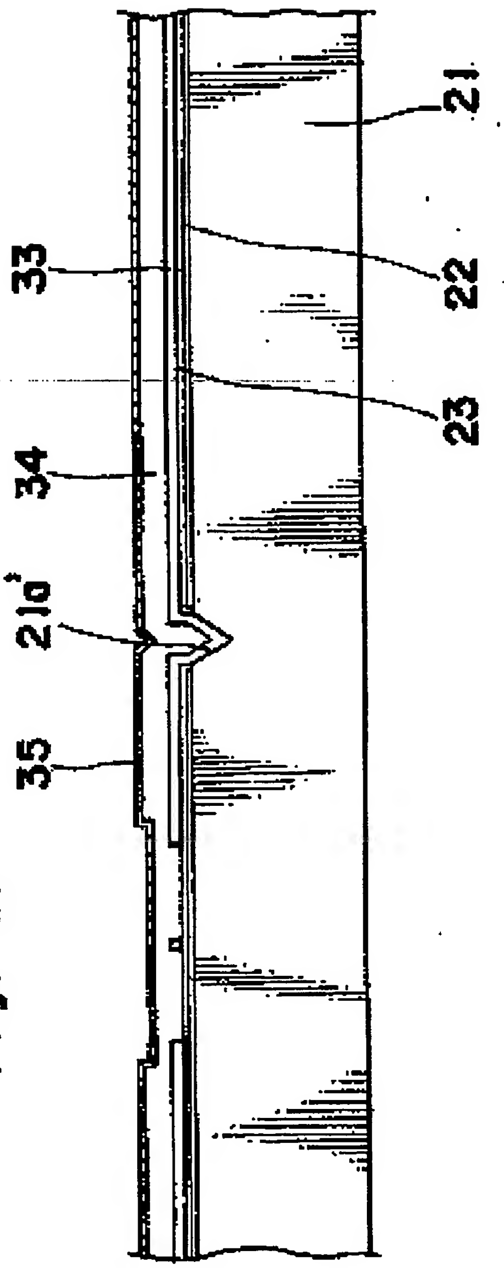

Fig. 8f

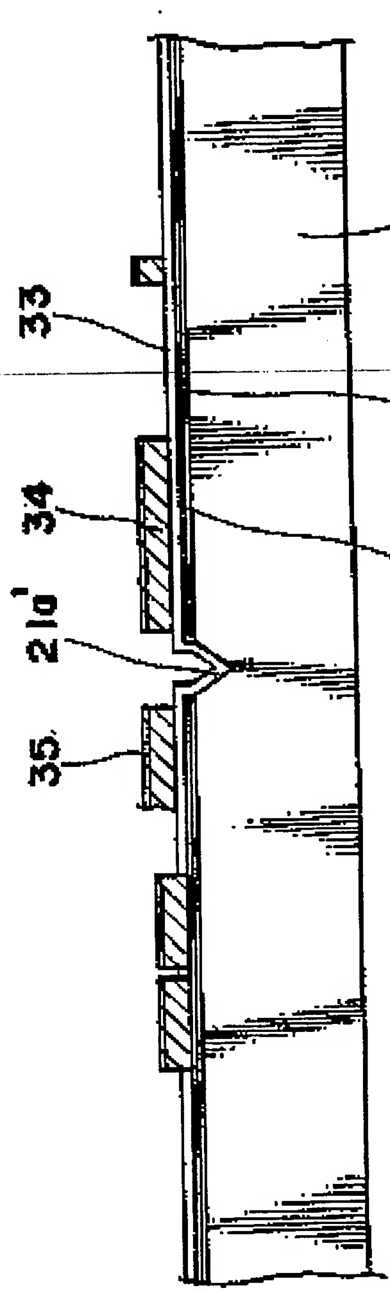

Fig. 8g

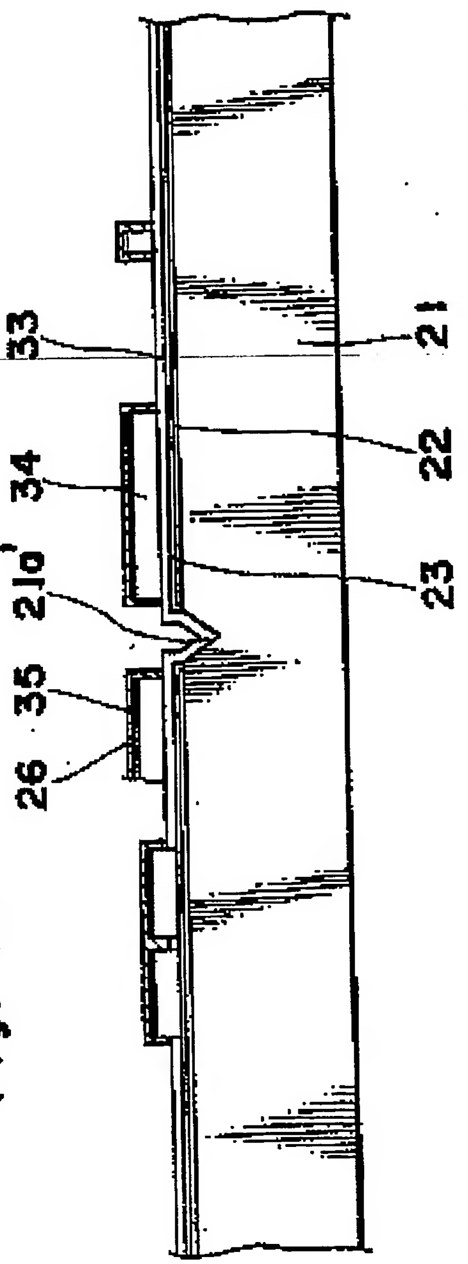

Fig. 8h

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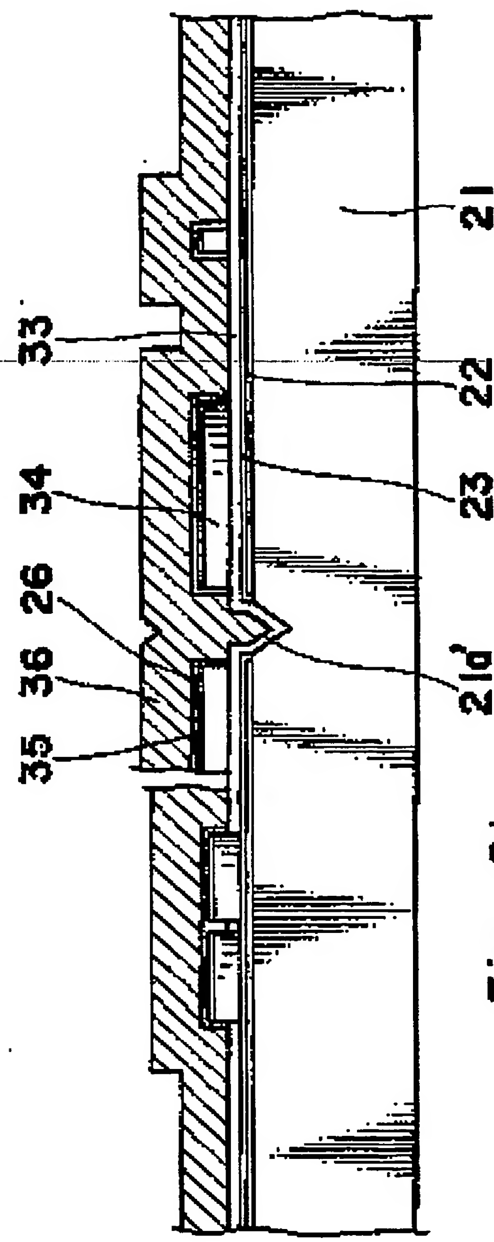

Fig. 8i

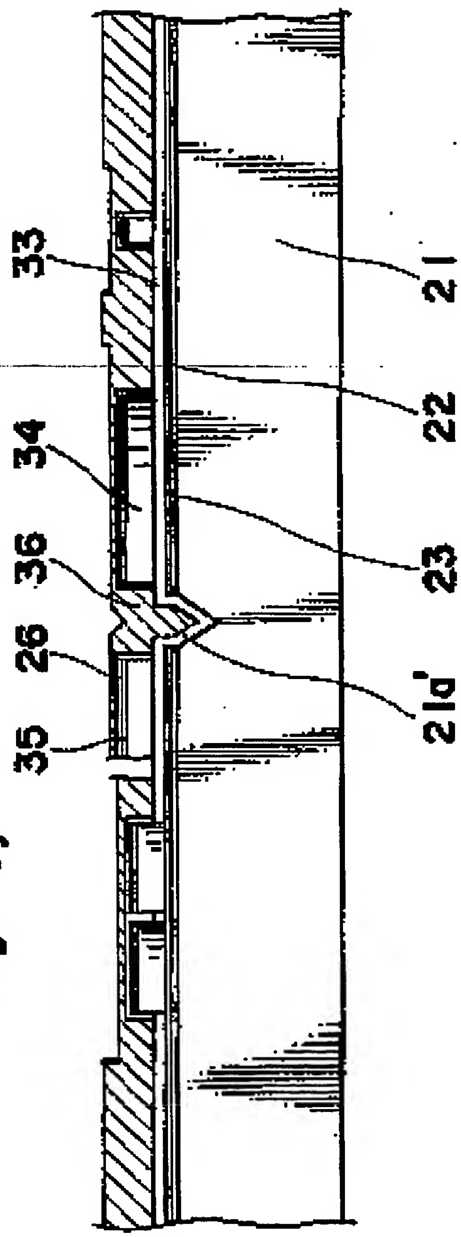

Fig. 8j

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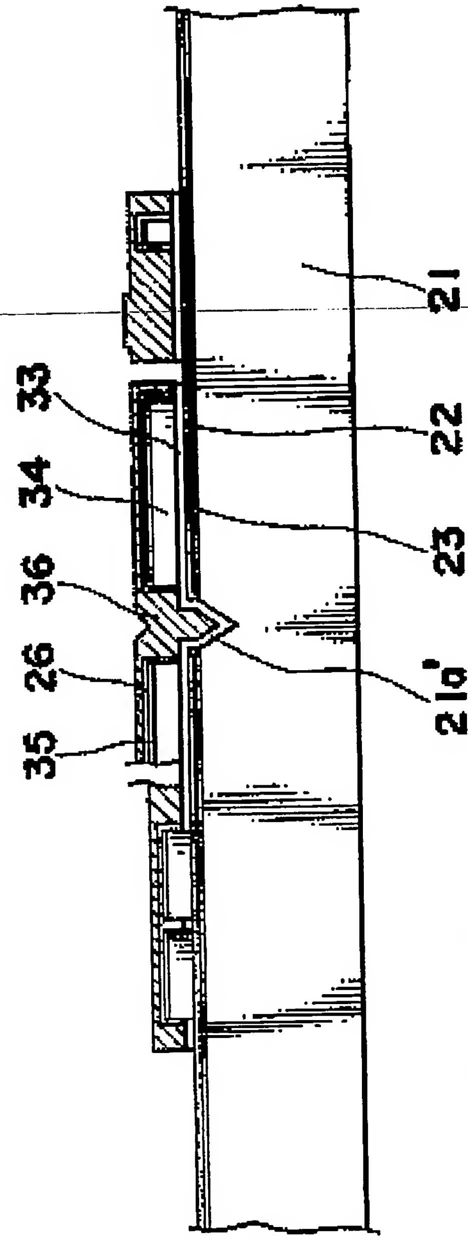

Fig. 8k

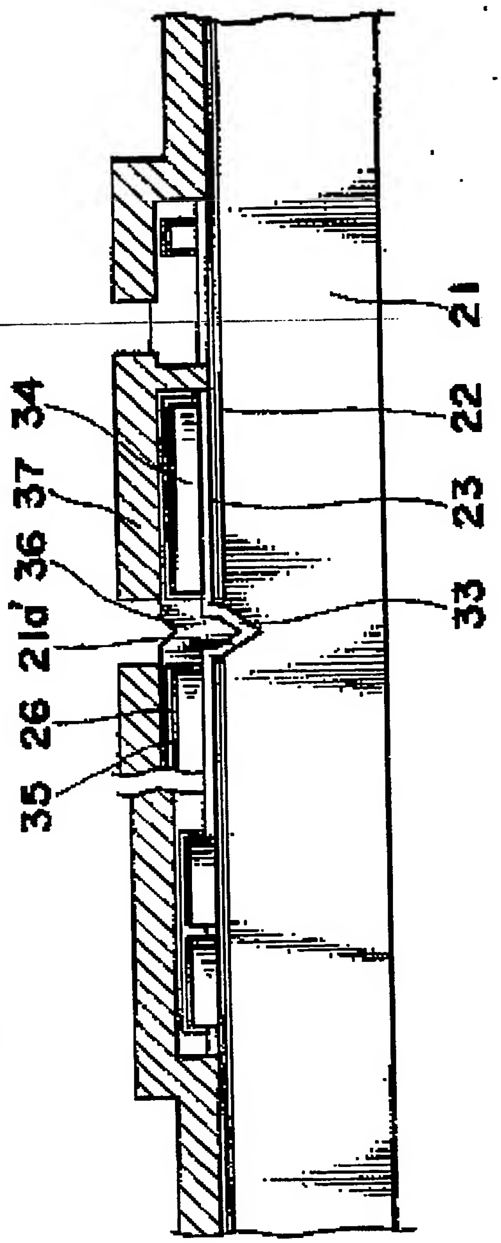

Fig. 8l

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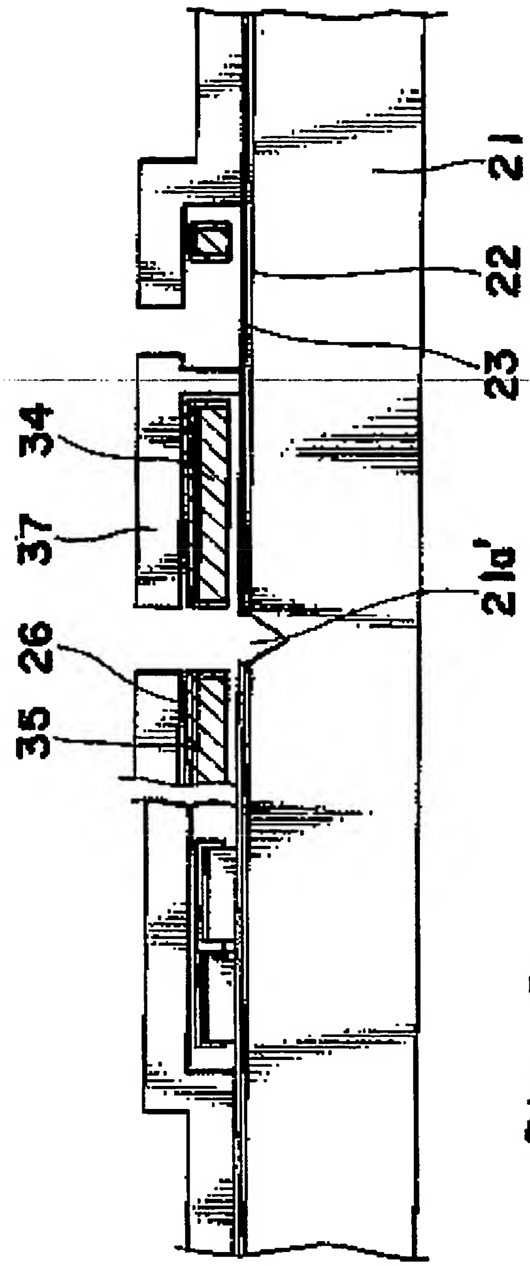

Fig. 8m

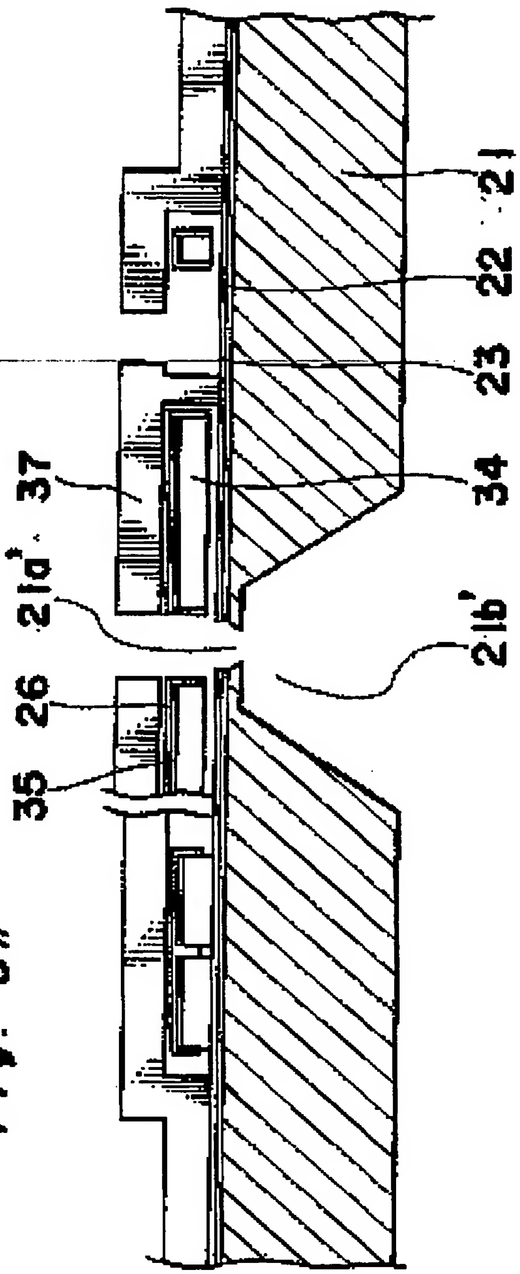

Fig. 8n

BNSDOCID: <EP___0431338A2TI_>

Fig. 9

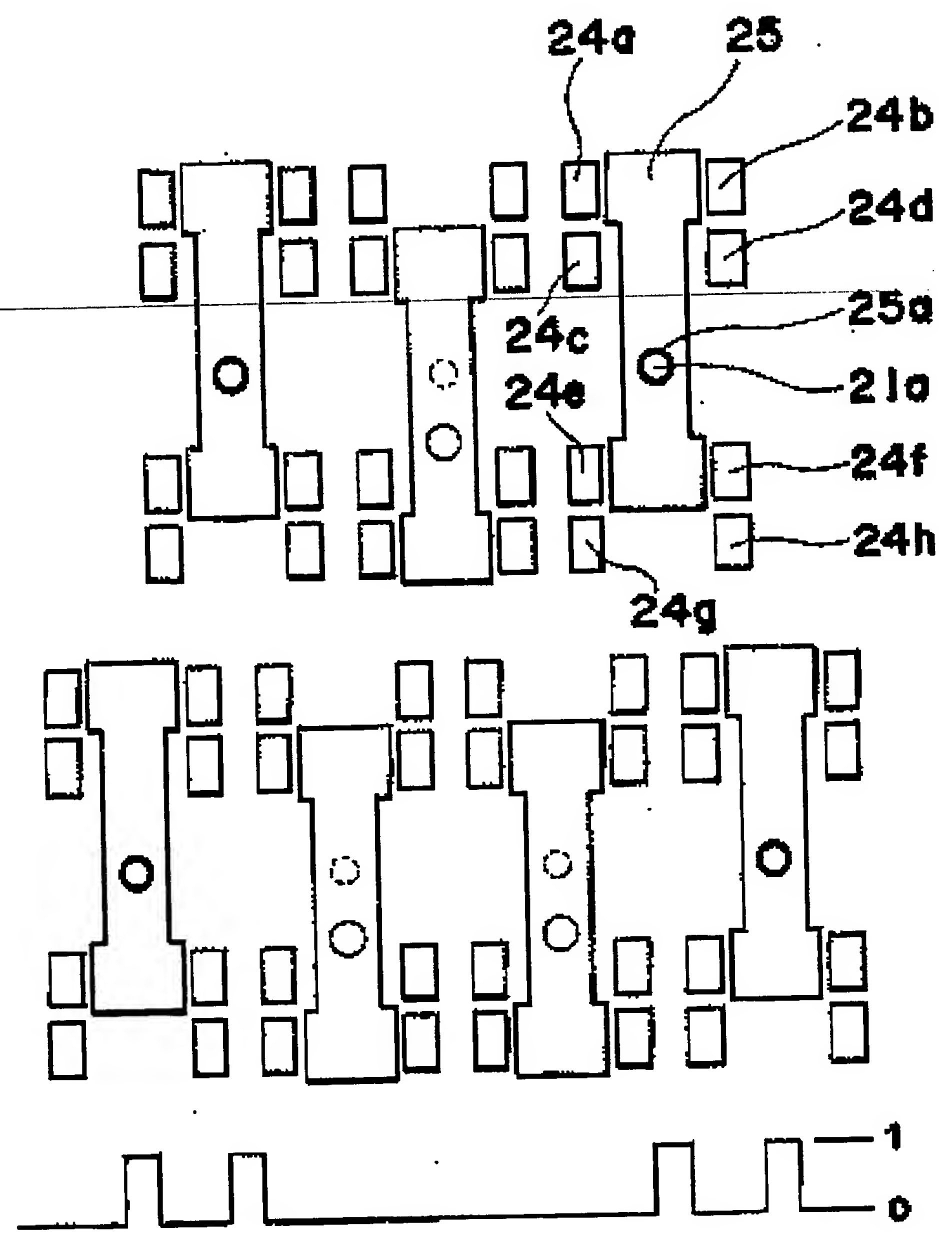

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Fig. 10

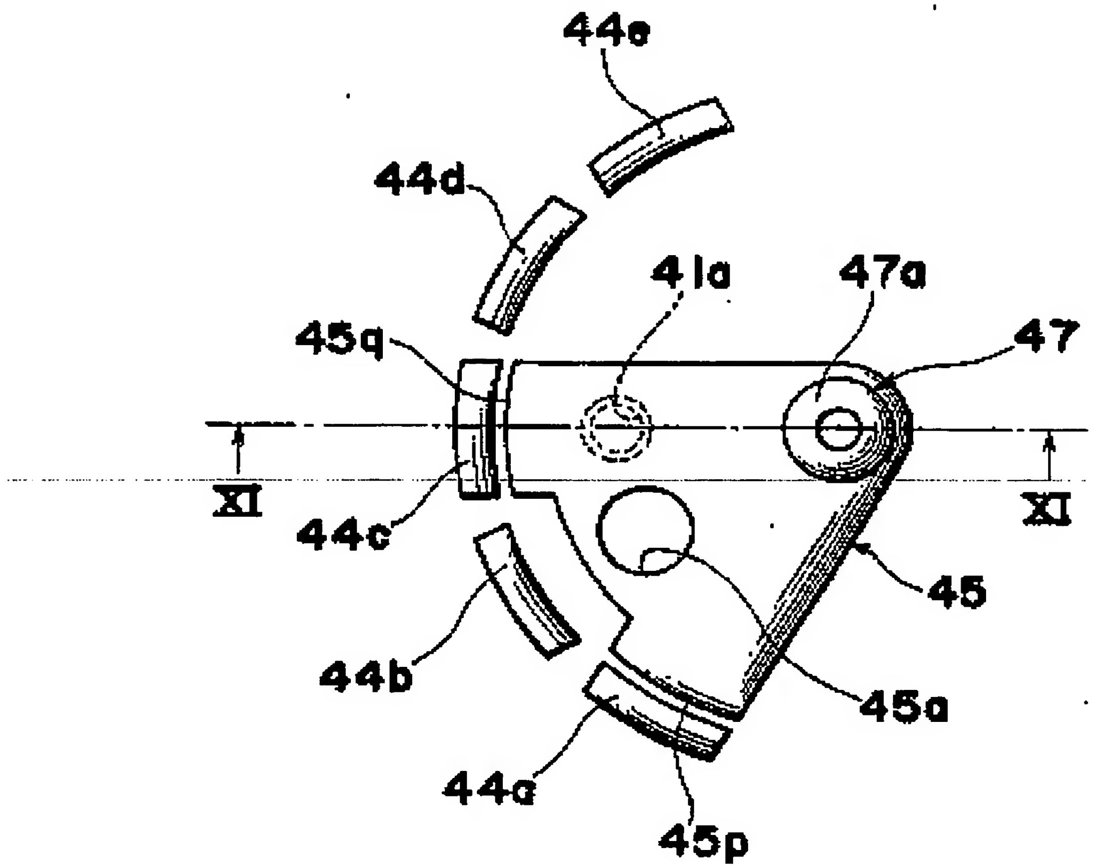

Fig. 11

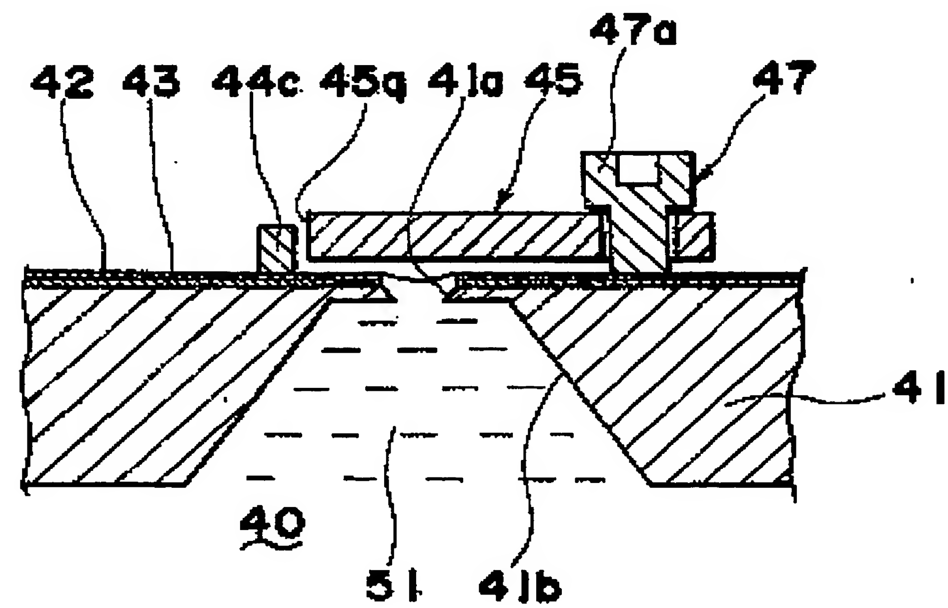

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Fig. 12

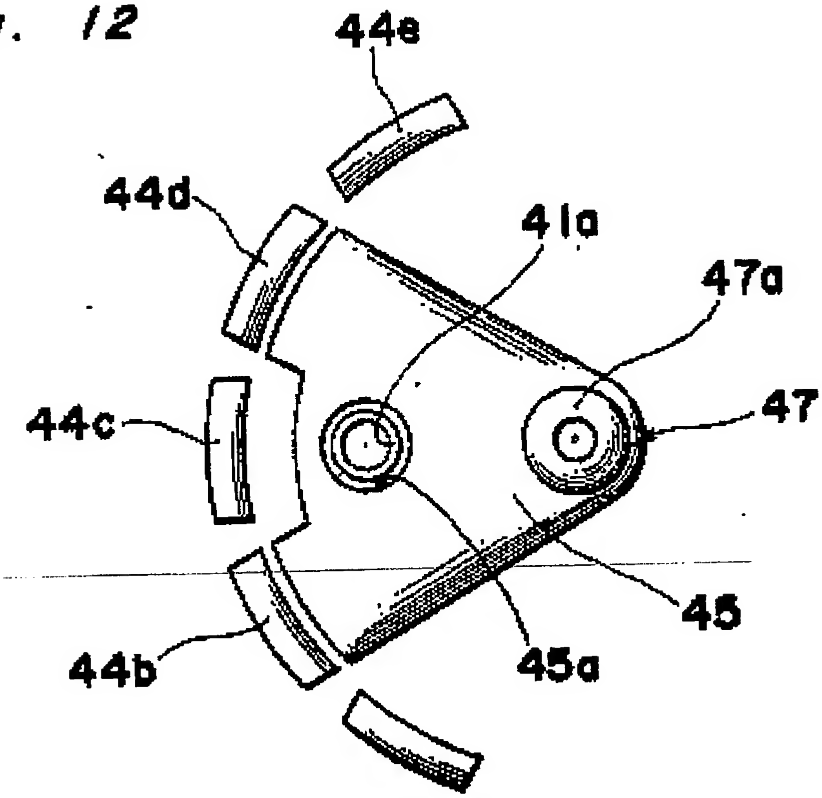

Fig. 13

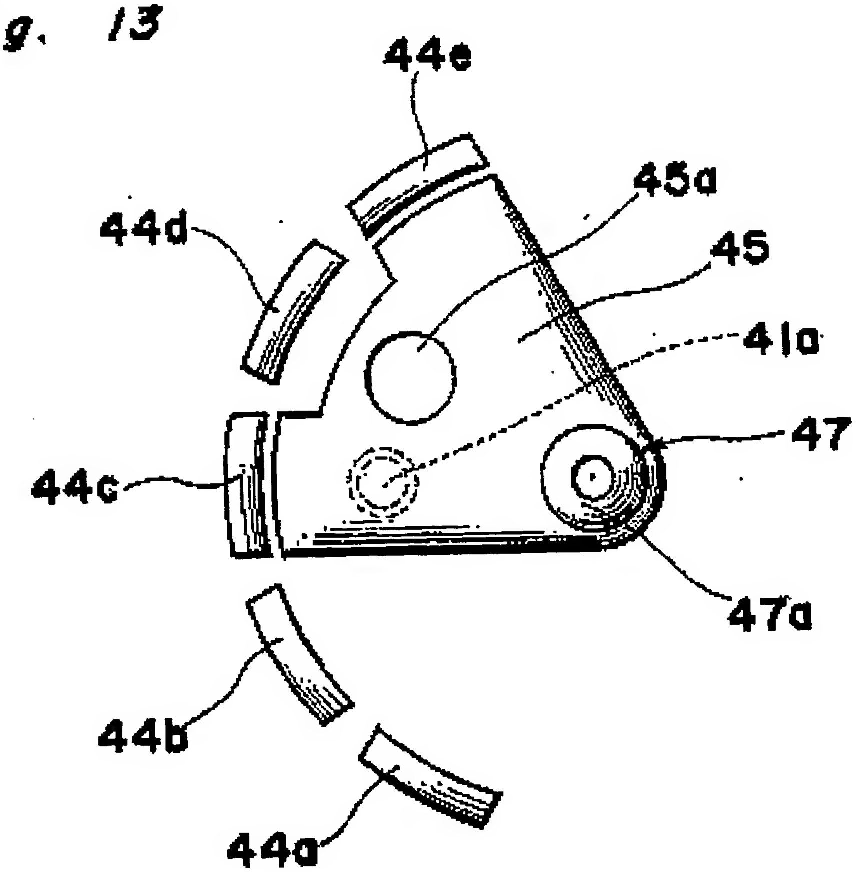

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Fig. 14 PRIOR ART

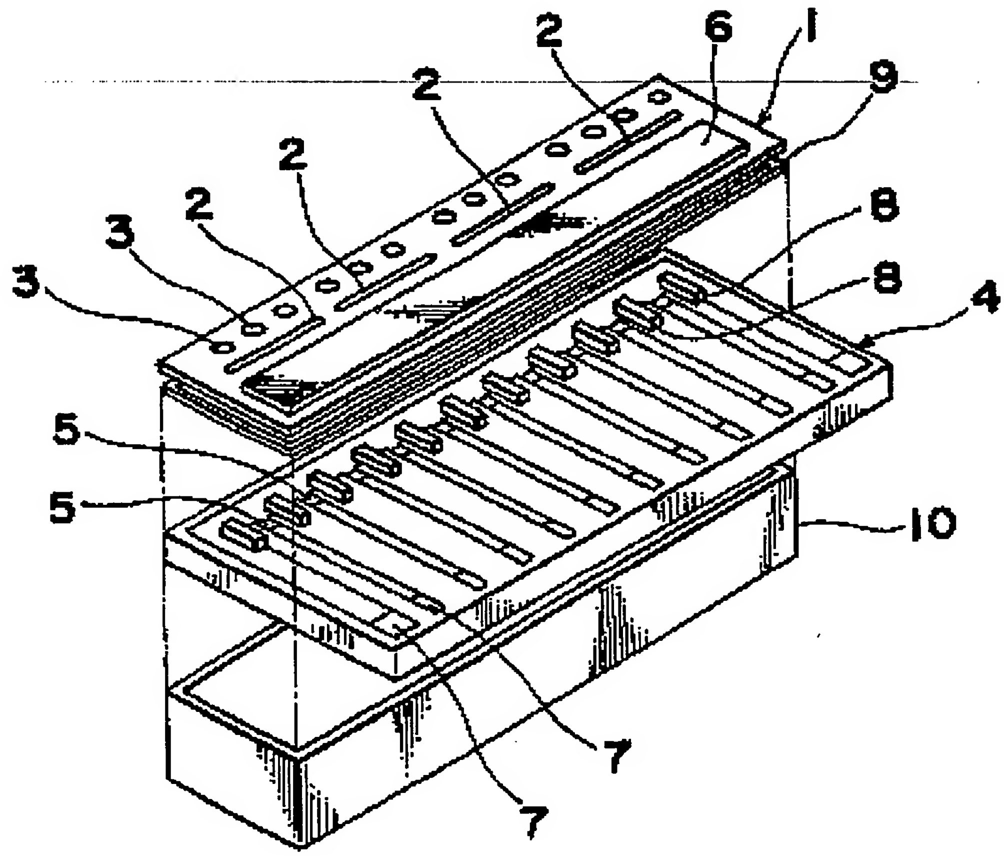


Fig. 15a
PRIOR ART

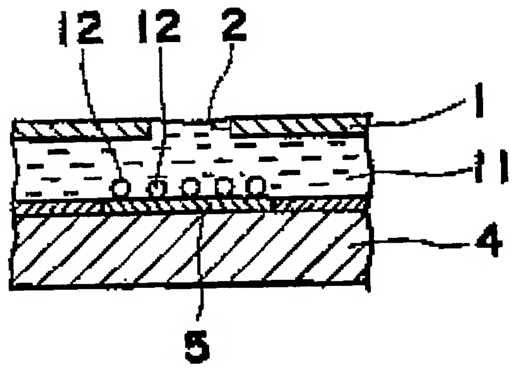


Fig. 15b
PRIOR ART

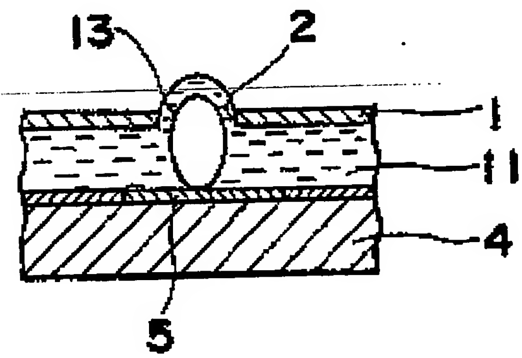


Fig. 15c
PRIOR ART

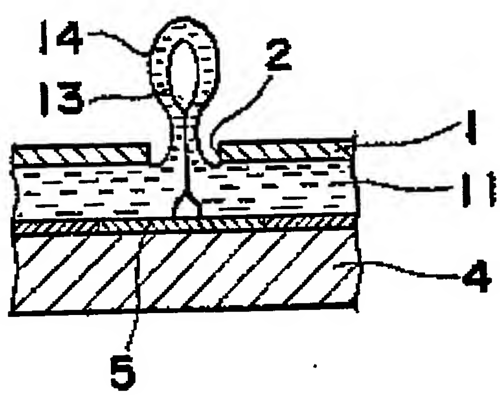
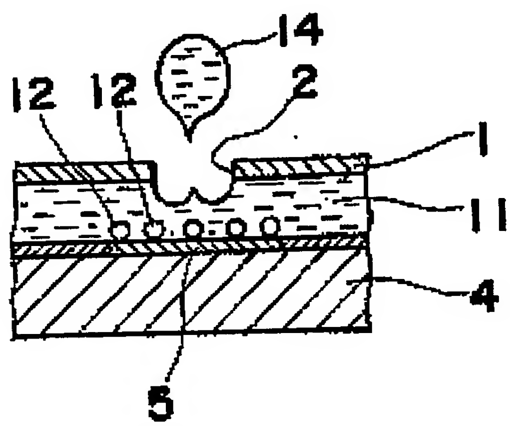


Fig. 15d
PRIOR ART



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⑪ Publication number: **0 431 338 A3**

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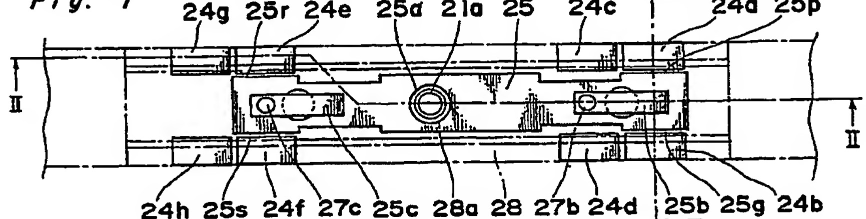
⑤④ **Ink recording apparatus.**

⑤⑦ An ink recording apparatus used with printers or the like and manufactured by applying semiconductor device manufacturing techniques. One wall of an ink chamber (20) is formed of a single-crystal substrate (21) and an ink jet port (21a) is formed by etching on the single-crystal substrate (21). The ink chamber (20) has a pressure-applying unit (60) therein, and the pressure is applied to ink within the ink chamber (20) so that the ink is jetted through the ink jet port (21a). The pressure-applying unit (60) has piezoelectric elements (60a). A shutter (25) and electrodes (24a to 24h) composed of polycrystalline-silicon film are formed on the single-crystal substrate by film forming in the LPCVD method and patterning through plasma etching. A front wall (28) is formed by coating the shutter (25) and electrodes (24a to 24h) further with a polycrystalline-silicon film. The shutter (25) is movable between the wall surface of the ink chamber (20) and the front wall (28), being driven through electrostatic attracting force produced between voltage-applied electrodes (24a to 24h) and the shutter (25). The electrodes (24a to 24h) are formed at positions corresponding to those where the shutter (25) blocks the ink jet port (21a) and releases the same.

Fig. 1



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European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 12 1374

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
E	EP-A-0 417 673 (MATSUSHITA ELECTRIC INDUSTRIAL COMPANY LTD.) * abstract; figures 1-6, 8, 9 * * column 4, line 35 - column 6, line 56 * * column 9, lines 13 - 18 *	1,2,5,7,8	B 41 J 2/16
X,A	US-A-4 199 767 (CAMPBELL ET AL) * abstract; figures * * column 3, line 31 - column 5, line 60 *	1,7,8	
A	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 22, no. 3, August 1979, NEW YORK US pages 917 - 918; Lammers G.B.: "Multi-nozzle Segmented Slider Valve" * the whole document *	1	
A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 318 (M-632)(2765) 16 October 1987, & JP-A-62 101445 (HIROSHI ENDO) 11 May 1987, * the whole document *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B 41 J

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	29 August 91	ROBERTS N.

CATEGORY OF CITED DOCUMENTS

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